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An Illustrated Weekly Journal

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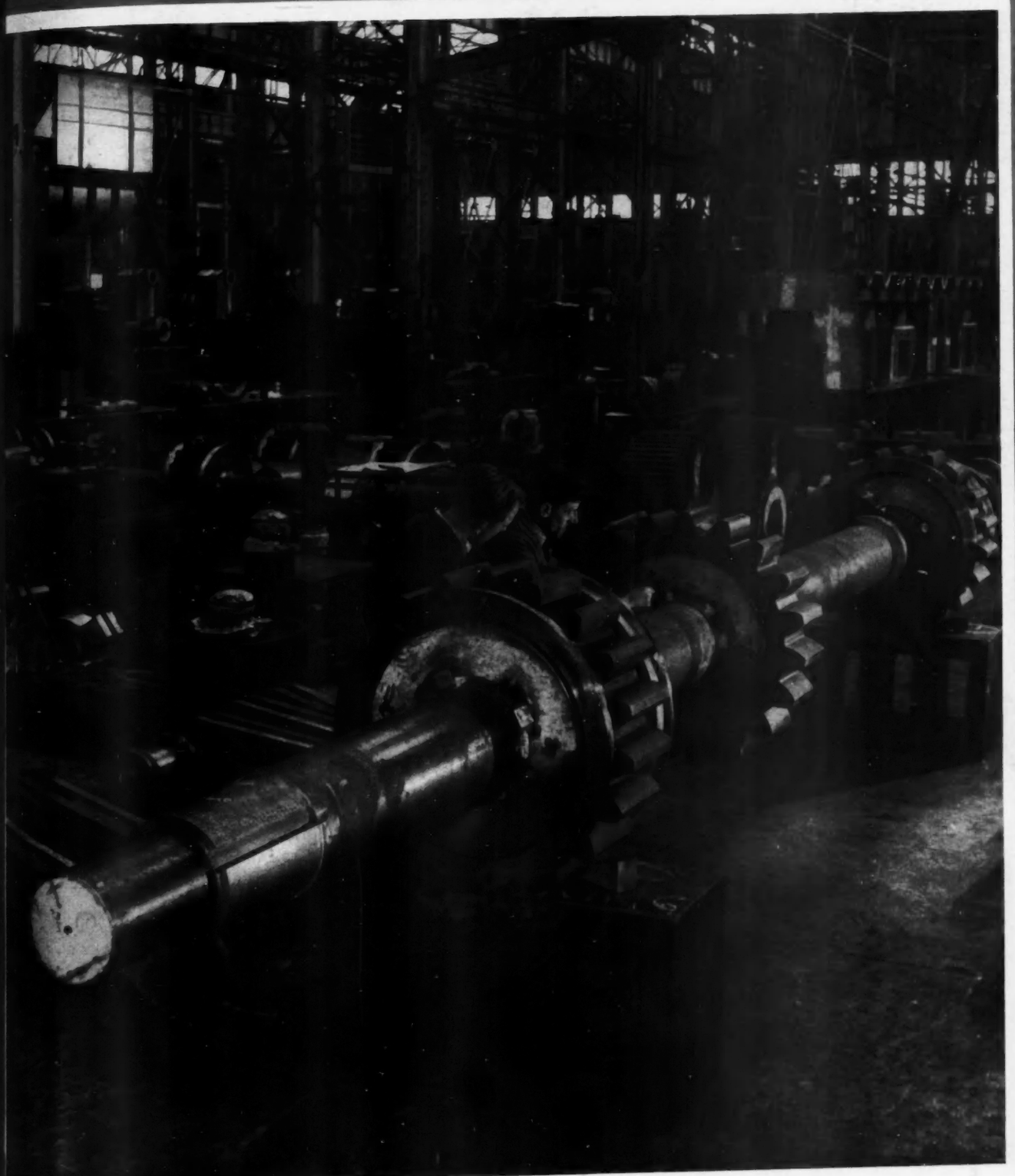
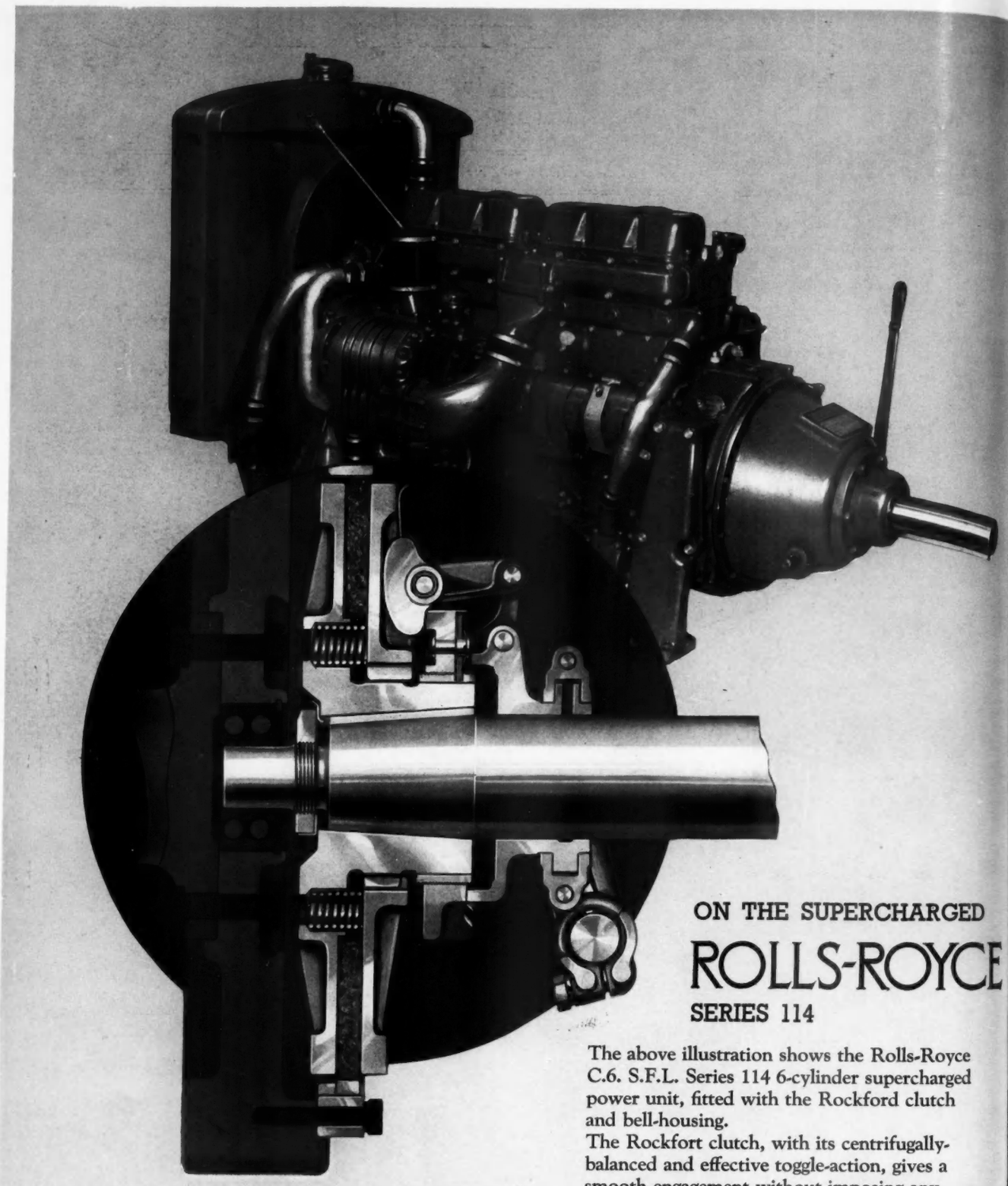


ROLLING-MILL MANIPULATOR SHAFT



ON THE SUPERCHARGED

ROLLS-ROYCE

SERIES 114

The above illustration shows the Rolls-Royce C.6. S.F.L. Series 114 6-cylinder supercharged power unit, fitted with the Rockford clutch and bell-housing.

The Rockfort clutch, with its centrifugally-balanced and effective toggle-action, gives a smooth engagement without imposing any running thrust either when engaged or disengaged.

British made, in a range of sizes, by
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ROCKFORD

POWER TAKE-OFFS & CLUTCHES

ENGINEERING

An Illustrated Weekly Journal

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INDEX TO "ENGINEERING"

Volume 180 now ready

The Index to Volume 180 (July-December, 1955) is now ready and will be sent to any reader, without charge and postage paid, on application being made to the Publisher, 35 and 36 Bedford-street, London, W.C.2. Any reader wishing to receive regular copies of the Index as they are published can apply to be put on the mailing list. Those already on the mailing list need not re-apply.

THE FOURTH DIMENSION

CURRENT talk about the prospects of a shorter working week sounds odd in the ears of executives who find there are not enough hours in the week for all they want to do. The trend is to cut out unskilled manual labour, but the change throws additional responsibility on mental labour. It looks as though we are developing a society in which the best brains will have to be protected from nervous breakdowns and those with fewer talents will have to be protected from boredom. The time factor is the awkward element. And it is a new awareness of the time factor which is affecting the thinking of all who do the planning and directing in industry. To-day it is not what you do; it is when you do it. In any industry the chances are that new ideas for development are not the monopoly of one person or firm; they usually arise more or less simultaneously at several points. The prize goes to him who acts first.

There is an opportunity this week to look at three contrasting approaches to the fourth dimension in engineering affairs. A review by the President of the Institution of Mechanical Engineers of motive power on sea and land since 1914 throws into relief the high spots in two of the oldest forms of engineering. A critical examination of the aircraft industry by one who has had experience of the Government and manufacturers' points of view shows that the best use of time has not been made in the development and production of aircraft. And the opening of Calder Hall power station reveals an almost miraculous use of time. A quick look at these three will have a bearing on the future—the most important part of the time element.

Addressing the Royal Aeronautical Society on "The Importance of Time in Aircraft Manufacture," Air Commodore F. R. Banks said that it seems to be quite commonly accepted that from seven to ten years are now required to design, develop and get a bomber to the production stage—but not necessarily into production. The aim must be, he suggested, to cut this time factor almost in half if an aircraft is to be of any real use to the Royal Air Force. Totals of man-hours required to develop certain jet fighters showed that although the figure had risen from 1,700,000 man-hours for an aircraft developed during the period 1945-49, it had risen to 4,800,000 for the period 1951-55. Yet the years of elapsed time had hardly changed, being just under 4½ years in the first case and just over 4½ in the second. He said that the cause of the present inferior condition of R.A.F. aircraft was partly due to the inordinate time taken to issue an Air Ministry requirement. Years elapsed after the first thoughts and not always the most timely aircraft or armament was chosen. Among the changes which he suggested were needed in order to halve the time factor were the selection of only one or two firms for tendering for a new aircraft, thus avoiding the wasteful use of valuable technical staffs; the creation of an adequate and efficient system of project evaluation; the greater use of "shadow" and sub-contracting schemes; the greater use of wind tunnels to ensure that prototypes, when built, performed and handled as the designers intended, without major and time-consuming modifications becoming necessary. The successful aircraft and engine firms, he believed, have usually been those who anticipated a need and came up with such an attractive proposal that it often formed the basis of an official requirement. The time scale again.

Mr. T. A. Crowe, in his presidential address to the Institution of Mechanical Engineers, looked back on his wide experience in marine and locomotive engineering. Between 1914 and 1951, the reciprocating steam engine and Scotch boiler in ships had given way to the steam turbine and the Diesel engine. On British Railways and most railways throughout the world the steam locomotive still predominates, but its development has not been as slow as was sometimes imagined. As Mr. R. C. Bond pointed out in his presidential address to the Institution of Locomotive Engineers three years ago, the rate of coal consumption on new locomotives on British railways was reduced by more than 30 per cent. in the 30 years from 1923 to 1953. Electrification of railways is being extended; so, too, is the use of Diesel locomotives, and Mr. Crowe's company are building a gas-turbine locomotive to run on pulverised coal. Compared with aircraft or atomic energy, these marine and railway developments are more gradual—for obvious reasons—but the importance of looking ahead is not lessened.

Atomic energy has achieved a tremendous impact on power production. Hopes expressed only a few years ago by the leaders in this field—which at that time must have seemed to be unduly optimistic—have had to be revised. Early in 1954, it was officially stated that within 20 years it might be possible to build reactor power stations which would save the country 20 million tons of coal per annum. It would be very surprising if this saving is not achieved, because now it is confidently hoped that by 1965 there will be 12 stations, or possibly more, with a total capacity of over 6,000 MW. Such a rate of progress in a branch of engineering which is so new is certainly not entirely due to the fact that it offers easily-

won opportunities, nor is it due entirely to the scale of expenditure which has been permitted. A good deal of the credit must go to the people who have organised the work of these last ten years.

Perhaps the concluding words of Air Commodore Banks are relevant to success in the fourth dimension:

"The lesson we should have learned from this past decade, albeit somewhat late, is that aviation has grown into big business and serious business, and that it cannot be run by a few people with ideas. It needs considerable foresight, first-class organisation and the elaborate facilities mentioned to get anywhere at all. But we can, and must, find a new formula in aviation by our undoubted engineering ability, always remembering that what still matters is to sell and to produce efficiently." The right product at the right time.

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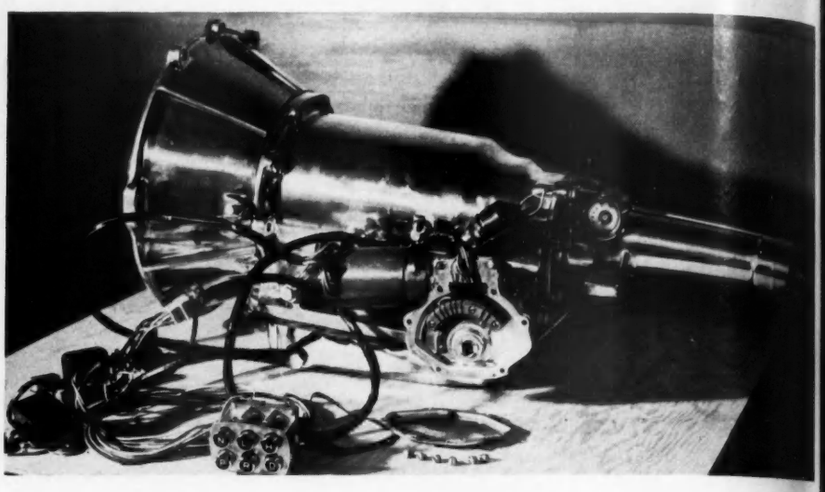
Plain Words

It is said that there is no such thing as bad publicity and that oblivion comes only from no publicity at all. This dictum was put severely to the test last week in the B.B.C.'s television programme from the International Motor Show at Earls Court, when a number of people were asked for their views on British motor-cars.

The motor industry is naturally sensitive about the views expressed on its products at a time when it is trying desperately to sell cars at home and abroad. It is not in the mood to have its efforts used as raw material for the evanescent entertainment of casual television viewers. While the Motor Show is on, the industry spends a large amount of money advertising its products and the advertising space is sold to it by publishers who make claims, which can be substantiated, about the extent of their readership. At one blow, a critical and not highly informed series of comments were injected into the minds of a potential audience of 5 million viewers.

On the other hand, the B.B.C. can claim that the occasion and the subject matter were of public interest and that it is their function to deal with controversial subjects and certainly not to avoid stimulating discussions. It is regrettable, however, that the probable outcome was not foreseen. The sample of people asked for their opinions on British cars were almost certain not to be representative and it is quite wrong to give the impression that these random interviews can have any similarity at all to scientific sampling. The techniques of interviewing on these occasions, too, evoke unthinking remarks and discourage considered, responsible opinion. Everyone concerned is under pressure to be quick rather than accurate. Rubbish is much better than silence. On balance, the conclusion is unavoidable that this performance did more harm than good and that the B.B.C., like the detective in the department store at a recent hat lifting episode, would have been well advised to look the other way.



Electrical control unit on the Packard Ultramatic transmission, showing the additional complication which has been accepted to provide control by push buttons instead of a lever.

ACCENT ON TRANSMISSION

By Gordon Wilkins

The outstanding engineering feature of this year's Motor Show is the immense activity on transmission developments, both to provide easier driving and to improve fuel consumption —two aims which are rarely compatible.

In the field of fully automatic transmissions, several new systems are under active development, but those now offered on British cars are confined to three types. The Rolls-Royce, based on Hydra-Matic patents, has been developed to produce almost imperceptible changes from its fluid coupling and four-speed planetary gear set, without recourse to the auxiliary fluid coupling which is filled and emptied to cushion gear shifts on the latest American version; the Borg-Warner, using a torque converter, lock-up clutch and planetary gears giving two intermediate ratios. The Rover uses a torque converter, planetary overdrive, and layshaft low gear.

The torque converter has undoubted attractions: lightness, if it replaces the engine flywheel, large heat capacity, smooth take-up and a reasonable production cost. Its disadvantages for the small European car are now familiar. Borg-Warner avoid the loss of efficiency in the coupling phase by using the lock-up clutch, a method used by Studebaker in America until 1955, but downshifts in British traffic driving are naturally more frequent than with an American car.

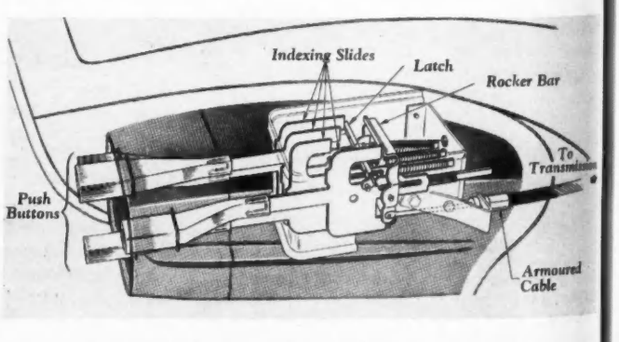
Use of a large converter with relatively low conversion can offset some of the disadvantages. This is believed to be one of the solutions which are under development by Ferguson in collaboration with Standard, by employing the converter geared down for the low-gear ratio. Rover, on the other hand, make middle gear the direct drive, using overdrive for high, and the layshaft gear for low and reverse.

The fussy take-off is a major defect of the converter in the eyes of the average user, with the engine rising to its maximum torque speed of around 2,500 r.p.m. For conditions where maximum performance is not required, this speed increase can be minimised by a device such as the variable-pitch stators; this is sufficient to hold the Buick at just over 1,000 r.p.m. on a light throttle. Another solution, not yet in production, but under active development, is to split the drive between the converter and gear set. A lock-up clutch also makes it possible, even on European cars, to use a "compromise" stall speed, provided there are sufficient gear ratios, as on the Borg-Warner units. It is becoming established that within the present limitations of the torque converter, a three-speed gear is a desirable accompaniment, for it remains true that, the greater the demands on the converter, the greater the need to dissipate waste heat. To-day's designs are no-where near finality.

The Borg-Warner automatic transmission, now fitted on many British cars and illustrated opposite, consists of a three-element torque converter, with lock-up clutch, and two epicyclic gear sets in series. The torque converter is operative in low and intermediate gears, giving a smooth progression from a total reduction of about 4·6 to 1 on low gear, to 1·435 to 1 as the converter reaches the coupling point on intermediate. The clutch then locks-up the converter for a 1 to 1 direct drive. Maximum input-output ratio of the converter is 2·16 to 1.

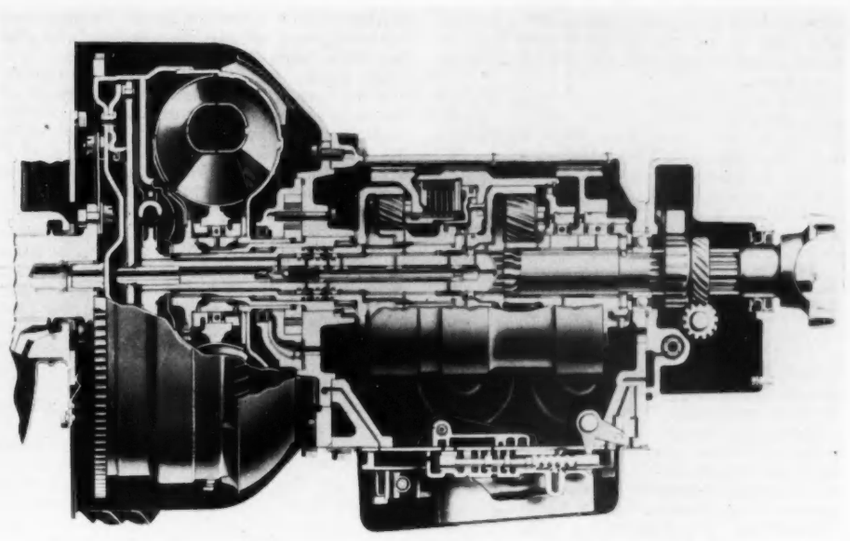
The transmission is controlled hydraulically, using a lever in a quadrant under the steering wheel, the pressure being supplied by two pumps, one at the front driven from the engine, and one on the output shaft and functioning only when the vehicle is moving. There is also a centrifugally operated governor valve coupled to the accelerator linkage.

When the lever is in "drive" position, changes up and down are made automatically according to vehicle speed and accelerator position. When



Chrysler obtain push-button control on the Powerflite transmission through a simple mechanical system, using a single control cable.

Daimler quandrant control for the Borg-Warner automatic transmission.



Borg-Warner automatic transmission now adopted by many British manufacturers and by Mercedes in Germany. It is fundamentally a design which has been proved in American service.

accelerating at full throttle, the lock-up clutch may not become operative until over 60 m.p.h. By moving the lever to the "low" position, the transmission may be held in low gear to provide engine braking on long descents. The engine can be started only with the lever in the "park" or "neutral" positions. In "park," a pawl engages with a gear on the output shaft and is capable of holding the car on steep gradients.

As adapted to European cars with relatively small engines of about 2½ litres, the transmission makes changes which are perceptible but not obtrusive. It cannot of course provide engine braking in the degree which an experienced driver would employ with a conventional transmission, for as the throttle is closed for a corner, it changes into direct drive, and the cut-in speed for low gear is too low to make this useful for the purpose. This difficulty has been met on the Jaguar by a small control on the fascia which holds the intermediate gear in use—a most important asset in mountains or on winding roads.

Rover are at present the only British manufacturers offering an automatic transmission which is entirely of their own design. It consists of a three-element torque converter, a single-plate clutch with vacuum-servo control, a two-speed and reverse synchromesh gearbox, and a Laycock de Normanville overdrive. A fully automatic-drive sequence is obtained through the torque converter and the direct drive in the gearbox to the overdrive, which engages automatically at a predetermined speed, subject to a kick-down over-ride switch on the throttle. An additional low ratio is obtained by moving a lever on the fascia to engage the indirect gear in the gearbox. A contact button on the gear lever then actuates a solenoid-operated valve which works the vacuum servo controlling the clutch during this operation. Reverse gear is obtained with the same lever.

Maximum torque multiplication with the converter is about 2·2 to 1, and the low ratio in the gearbox provides a further reduction of 1·74 to 1. The overdrive, which operates only when the gearbox is in direct drive, has a ratio of 0·77 to 1. With an axle ratio of 4·7 to 1 the transmission therefore provides a normal-drive range between 10·2 to 1 and starting to 3·62 to 1 with the overdrive engaged and the converter functioning as a coupling. The overdrive is engaged at speeds between 30 and 70 m.p.h. according to throttle position, and a return to direct drive can be obtained within this range by kicking down on the accelerator.

Aluminium castings are used for the converter, and the whole transmission employs existing elements or parts which can be made easily with existing equipment. Moreover, it can be serviced without specialised knowledge.

Among the devices which are now moving from the development to the production phase is the electromagnetic powder clutch, invented by Jacob Rabinow and developed by S. Smith and Sons, and the automatic three-speed transmission based upon it. The rights in the powder clutch for all countries outside the United States were acquired from the Eaton Manufacturing Company three years ago, since when, Smith's have spent a great deal of money on its development. Rabinow departed from the normal conception for the friction clutch, and obtained the drive by passing a magnetic flux through an iron powder contained in a narrow annular gap between the driving and driven members. While current is flowing through the windings of the excitation coil, the powder becomes virtually a solid mass, the torque transmitted being proportional to the excitation. There is sufficient heat dissipation capacity to allow the clutch to slip over a wide range without damage, giving a very smooth take-up, and within reason it is possible to hold the car on a gradient by use of the accelerator only.

Smith electromagnetic powder clutch.

The original invention was based on the use of iron powder suspended in oil, but Smith's use dry powder, so eliminating the sealing problems. Difficulties were experienced owing to the oxidation of the powder, which produced a rapid fall in efficiency, but this has now been overcome by use of a chromium-iron powder.

The principle can be employed in various ways, but in the form at present used, there is a normal engine flywheel with starter ring, to which is bolted a steel casing containing an insulated electric coil fed with electric current through a slip ring and brushes. An output member of smaller diameter runs in a recess within the magnet casing, leaving a thin annular space of a few thousandths of an inch between the two, in which the iron powder lies. The device has the smoothness of a fluid coupling, but the drive can be disconnected by simply cutting the current supply, regardless of engine or road speed, so that it is fundamentally smoother than any clutch depending on friction, where the friction between the mating elements is higher at take-up than it is with the plates fully engaged, thus tending to produce judder. For progressive initial engagement, the clutch is supplied with current from the car generator, but above about 10 m.p.h. current is taken from the battery. The drive is disconnected during gear changing by a switch built into the gear lever, so that no clutch pedal is required. Current consumption for a normal private car is about 50 watts.

To give an acceptable two-pedal control system, various refinements are necessary. Two mercury switches, so placed as to be sensitive to acceleration and deceleration, but not to centrifugal force, reduce the excitation current when the car is not accelerating, so as to limit the decelerating torque transmitted by the clutch, thus smoothing out gear shifts on a light or closed throttle. An extra switch, engaged in top gear, cuts out the mercury switches and ensures full torque transmission at maximum speed. The act of putting a hand on the gear lever does not simply break the current flow to the windings; it also makes a contact which in effect reverses the polarity of the clutch coil, thereby ensuring an immediate disconnection of the drive. A resistor in the circuit nullifies the effects of remanence during this phase.

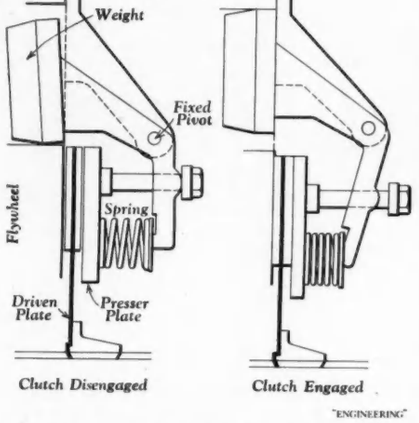
A further switch connected to the choke control

brings another series resistance into the generator field circuit when the choke is operating, so giving normal clutch operation with a high engine idling speed.

The clutch is being offered to manufacturers as a substitute for the normal type, for use in conjunction with a standard gearbox, but Smith's have also developed a fully automatic three-speed transmission using two powder clutches in conjunction with a specially adapted layshaft-type synchromesh gearbox. One clutch allows a direct drive, the other provides two intermediate gears or reverse by means of sliding gears operated by an electric solenoid.

This transmission is known as the "Autoselectric." Shift speeds are determined by a governor sensitive to road speed and throttle position; a built-in hysteresis effect ensures that downshifts are made at lower speeds than upward changes. An over-ride is provided to allow the driver to hold second gear.

This system works well on the road: power-sustained shifting is possible, and although the changes are perceptible they are not abrupt. As at present applied, there is of course an increase in the rotating mass on the clutch shaft, which makes extra demands on the synchromesh mechanism. This is met in the Smith's automatic gearbox by use of a free wheel, plus baulk rings, and an electrical arrangement which momentarily engages one of the clutches to control the engine speed. On normal transmissions to which the Smith's or other automatic clutches are applied, there is likely to be a demand for more effective synchromesh mechanisms, coupled with an overdue application of synchromesh to bottom gear, as is already in widespread use on the Continent. This accounts for the interest now being taken in devices such as the Porsche servo-ring synchromesh which has proved very effective on a number of sports and racing cars.



Newtondrive centrifugal clutch: mechanical details.

The magnet windings add appreciably to the rotating mass of the flywheel, especially where two clutches are used, as on the automatic transmission. The effects could be minimised by using a clutch of reduced diameter, possibly at a cost of an increase in length, but it is not impossible that such a clutch could be made to work by a radical re-design using stationary windings.

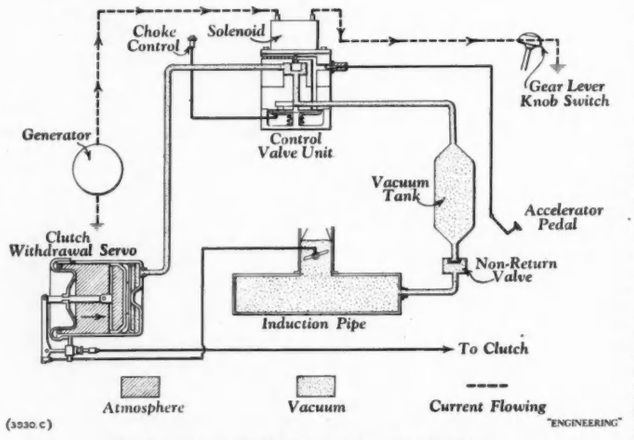
Another application of this clutch now under active development is in the cooling fan. On large engines, the fan consumes several horsepower at high speeds. It is noisy and tests have shown that it may only be needed for about 5 per cent. of the running time. A powder clutch, actuated by a thermostat in the cooling system, could effect useful economies by bringing the fan into use only when it is really needed. It will be recalled that Ferrari use an electrically driven fan on touring models, and this can be switched on when required.

Of the two automatic clutches now in production in England, the Newton, used by Standard, is the simplest and cheapest. It is a centrifugally loaded single-plate clutch, withdrawn by a vacuum servo piston which is controlled through a solenoid switch operated by a small button on the gear lever.

In the past, centrifugal clutches capable of being withdrawn while running above the critical speed have used both pull-off springs and driving springs. The Newton design uses one set of springs to perform the dual function, so reducing the mass required in the centrifugal weights. When running free below 800 r.p.m., the weights are in the position shown on the left of the illustration on this page depicting the mechanical details. A projection on the lever carrying the weight forms a fulcrum against a nut on a bolt on the presser plate. The spring, working round this fulcrum, causes a reaction at the fixed pivot which withdraws the presser plate from the driven plate. The weight bearing against the inner face of the flywheel recess limits the withdrawal. As the speed rises, the weight flies out and the presser plate is progressively loaded through the springs. Another lever system, operated by the servo piston, withdraws the presser plate against the action of the springs, leaving the weights in the out position.

During gear changing, a cable connection from the servo linkage opens the throttle slightly, irrespective of accelerator position, to prevent snatch on re-engagement. The driver need show no skill except in speeding up the engine for a quick downshift.

Another refinement is an extra air valve connected to the accelerator, which breaks down the servo depression more quickly and ensures more rapid clutch engagement when fast gear shifts are made. An additional valve connected to the choke control alters the porting in the control unit, and prevents clutch engagement when the engine is idling fast. Use of the accelerator overrides this, so that the car can be driven away normally. Downhill engine braking is retained provided the connection is not deliberately broken by pressing the knob on the gear lever, when the engine must be accelerated to restore it.



Newtondrive centrifugal clutch: circuit diagram.

The Manumatic system, made by Automotive Products and adopted by Armstrong Siddeley and the B.M.C. is more complicated, and costs much more. It consists of a centrifugal clutch under vacuum servo control which is actuated by a gear lever switch, with two additional servo units to take complete charge of the throttle during gear changing. One of these, the throttle-closing servo, is in circuit with the clutch-operating system, and normally closes the throttle as soon as a gear change begins. The other is operated by a two-part synchronising switch connected between the clutch cover and the driven plate. This is a throttle-opening servo, which over-rides the throttle closing servo should the engine speed fall below the speed of the driven plate. On both systems an auxiliary control can be provided to engage the clutch manually so that the engine can be started by towing or pushing the car.

This is the second of the articles, which are to be continued, reviewing progress in the motor industry, with particular reference to the Motor Show. The first article appeared on page 500 last week.

* * *

Letters to the Editor

PHYSICAL MEANING OF SECTION MODULUS

SIR, In reply to Dr. E. H. Bateman's letter, published in your issue of September 21, page 357, I can only restate that the section modulus S is (numerically and in terms of physical dimensions) identical with the "unit-stress-moment" M_1. This was the main point of my initial letter. As a consequence of the definition, the larger the "unit-stress-moment," the smaller the maximum stress, i.e., the stronger the beam.

The use of mutually reciprocal quantities (i.e., resistance-conductance, impedance-admittance, capacitance-elastance, etc.) is common in the field of electrical engineering because of convenience in dealing with parallel and series circuits. The latter are frequent also in the field of elasticity.

Yours faithfully,
MICHAEL DANILOFF.

Special Systems Section,
Raytheon Manufacturing Company,
Wayland Laboratory,
Wayland,
Massachusetts, U.S.A.
October 12, 1956.

* * *

EXPORT TRADE

SIR, Mr. Cyril Lord is quoted in ENGINEERING of October 19 (page 486) as saying:—"No export business can be built except on a solid home-trade foundation." This view, though often stated by others, must be a complete fallacy. The home markets of Switzerland, one of the most highly developed industrial countries, are very small in any case; they are negligible for her major industries, and do not exist at all for some of them, for example, heavy marine Diesel engines.

It would probably have been better if the many industrial commissions which went to the United States of America after the war had studied Swiss methods. Their problems are nearer to ours in the necessity to export manufactured goods to pay for imported food and raw materials. America is, relatively speaking, not interested in export trade at all. Our existence depends on it, and we must develop our methods for competing with other nations in it, or we starve.

Yours truly,
HUGH CLAUSEN.

Kingston Lodge,
Bradford-on-Avon,
Wiltshire.
October 22, 1956.

Weekly Survey

Cover Picture: *The illustration this week shows the checking of the keys on the main driving shaft of the manipulator of a* 42 *in. by* 108 *in. high-lift reversing blooming and slabbing rolling mill. The mill is designed to roll slab ingots up to* 12 *tons, and square ingots up to* 4½ *tons in weight, in outputs ultimately reaching* 650,000 *tons in a year of* 6,000 *working hours.*

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The British in India

To coincide with the arrival of the British Heavy Engineering Mission in India, the Federation of British Industries has published a survey of Indian industrial development. The survey points out that, under the second Five-Year Plan, India proposes to import machinery and equipment totalling about £1,000 million. This can be divided very roughly into £700 million on Government account and £300 million for private industry. The Government expects to purchase abroad about £300 million of transport and communication equipment, over £200 million of industrial equipment and about £127 million of plant for irrigation and power projects.

The Government of India has also prepared a memorandum for the Mission showing the anticipated requirements for the third Five-Year Plan. The pamphlet points out that decisions to buy machinery for the second Five-Year Plan involve taking a view of production requirements under the third Five-Year Plan. In consequence, targets to be achieved by 1966, when the third Five-Year Plan will be due for completion, have been set up for 20 key industries. These include iron and steel, aluminium, cement, ferro-manganese, fertilisers, petroleum, dye-stuffs, pharmaceuticals and paper. Requirements of machinery in the first year of the third Plan, which will be for 1961—62, are put at about £192 million and this is expected to increase to about £270 million in 1965-66.

These figures are obviously only tentative, but they suggest the scale of the investment programme and make it abundantly clear that any country exporting capital equipment wishing to establish itself in the Indian market during the course of that country's long-term development programme must do so from the start, though the competition may be stern and the risks substantial.

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Free-Piston Engine Development

Two interesting announcements were made last week regarding the application of the free-piston engine in this country. Scottish Ore Carriers Limited have ordered from Lithgows Limited an ore-carrier of approximately 8,000 tons deadweight to be powered by a 2,500 s.h.p. exhaust gas-turbine driven by three GS-4 piston-type gasifiers. In addition, the Billingham division of Imperial Chemical Industries have decided to use the Pescara free-piston engine system to drive, through gas-turbines, three large rotary gas compressors. This installation will use fifteen 1,000 h.p. GS-34 gasifiers.

Development on the Pescara free-piston engine was undertaken some years before the war by Alan Muntz and Company, Limited. An exclusive licence to produce engines up to about 300 h.p. and a non-exclusive licence for those above 300 h.p. have been granted to the Free-Piston Engine Company, a subsidiary of Associated British Engineering, and it is this company which, in conjunction with S.I.G.M.A., the French licensees, will supply the engines for the two applications mentioned above.

For marine propulsion, the free-piston engine has already been in use for some time in two French coastal cargo ships, and the first British merchant ship to be fitted with a free-piston gas generator will be starting sea trials in a few months time. This engine is expected to be of about 3,000 s.h.p. In the United States, where development is in the hands of General Motors, a 6,000 h.p. set is being installed experimentally in a converted Liberty ship.

In announcing their decision, Imperial Chemical Industries stated that the main features of the free-piston engine which make it very suitable for the supply of continuous power for a chemical processing plant are the wide range of fuels which can be used; and also the fact that the power is divided between a number of independent operating units, each of 1,000 h.p., with the final drive coming from turbines, the characteristics of which can be matched to the performance of the rotary compressors.

These developments, occurring within a few months of the formation of the Free-Piston Engine Company, augur well for the future expansion of free-piston engineering in this country, which appeared at one time to be falling behind that in some countries abroad, in spite of the large amount of development carried out over a period of years in the United Kingdom.

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Aircraft in Half the Time

In quality of equipment the Royal Air Force now probably takes fourth place, after the United States, Russia and Sweden. This situation has arisen partly because the Air Ministry takes an excessive length of time to issue its requirements, and partly because the aircraft manufacturers awoke too late to the extent of the technical problems they had to overcome. This was the thesis put forward by Air Commodore F. R. Banks, director of the Bristol Aeroplane Company, Limited, in a lecture on " The Importance of Time in Aircraft Manufacture " given recently before the Royal Aeronautical Society in London. To remedy the sickness of the industry, Air Commodore Banks recommends a " sink or swim " policy in ordering new aircraft, and, as a corollary, the fostering of larger technical and production units.

It should be possible, he believes, to reduce by about a half the time required to design and develop an aircraft to the production stage. One of the reasons why the Air Ministry is slow in framing its requirements is the lack of continuity of the personnel—general duties officers of the Royal Air Force—of the operational requirements section of the Ministry, and their lack of a high degree of technical knowledge. To overcome this, he suggests, a corps of highly-qualified engineer officers should act as " continuity sisters " to the operational officers. To speed up the issue of requirements to the industry, the Air Ministry and Ministry of Supply teams should work under the same controller in the same building.

The practice of putting a requirement out for general tender is, he believes, wasteful in the use of firms' technical staffs, and he would prefer to select only one or two likely firms. Contracts should be awarded only to firms with adequate technical and engineering strength to ensure that they can complete their commitments in reasonable time. The Ministry's assessment team, therefore, must be not only capable of evaluating the merits of the designs put up to them, but must also be capable of analysing the firm's capacity for doing the job at the desired rate. Much the same considerations apply to the procurement of commercial aircraft, but here there should be a more direct link between the national air-lines and the industry. There is, he thinks, no future for a large British subsonic air-liner in competition with the American projects, and at present a very problematical future for a supersonic air-liner; but up to 150,000 lb. all-up weight, there is still scope for British engineering ingenuity, based on searching market assessments and accurate scheduling.

Growth of the Radio Industry

In his address as new chairman of the Radio and Telecommunications Section of the Institution of Electrical Engineers (which he delivered on October 17), Dr. R. C. G. Williams gave some striking figures of the growth of the radio industry. Although the thermionic valve dated from 1904, it was not until the First World War that production took place in any quantity and permitted the generation of continuous waves suitable for the communication of speech and music. The radio receiver industry had been unique in growing out of an already established component industry. This was due to the widespread home manufacture of simple receivers from kits of parts an operation which became too complicated for the layman with the introduction of the mains-operated valve and the moving-coil loud speaker. As a result many new receiver manufacturers were able to start up in the early thirties with very little capital, since they could obtain components from an industry which had previously been manufacturing directly for the public. The present size of the industry could be illustrated by saying that it employed 200,000 persons in about 225 companies with a turnover last year of some £200 million in equipment and components, of which £34 million represented exports. New developments were, however, changing the character of the industry; and it was predicted that in ten years time nearly half its turnover would be represented by capital goods arising from the growing demands for sources of power and means of controlling it for industrial use. Whether we should be able to take advantage of this opportunity would depend largely on the supply of engineers, technicians and craftsmen. The outlook was disturbing, but the need was obvious and called for immediate action.

Turning to more technical matters Mr. Williams said that the post-war years had seen the development of a number of new devices derived from research into materials. These included semi-conductors which, from a manufacturing point of view, presented a problem in controlled impurity as distinct from the classical chemical problem of controlled purity. In production the basic material must first be purified to a degree far beyond normal manufacturing tolerances and to this pure material must be added microscopic amounts of the order of one part in one million of an equally " pure " impurity. Many ingenious methods were being developed for growing pure crystals and subsequently treating them by " zone refining." Electronic methods of measuring their purity were available, but pharmaceutical standards of cleanliness and a fundamentally different outlook in the factory were required.

In making use of semi-conductors, the vacuum with which most of our electronic work had so far been concerned was being replaced by an artificially produced crystal lattice. This material was difficult to control and inspect for flaws and the manufacturing problem lay in mass production to consistent tolerances at a cost which would take advantage of the low material price. Research work was also being directed to producing more efficient phosphors with wider ranges of stimulation and emission radiation and of persistence. Ferrites had applications using the hysteresis loops they could be made to exhibit, and like transistors they had obvious applications to mobile and portable apparatus where the saving of battery weight or the use of an already available low voltage supply was alternative.

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Experiments with Colour Television

The British Broadcasting Corporation will begin its third series of colour television transmissions from the Crystal Palace station on November 5, using Channel I (vision 45 megacycles and sound 41·5 megacycles). The system of transmission will be the same as that used in

the previous experiments from Alexandra Palace in October, 1955, and in April of this year. It consists of a modified version of the American N.T.S.C. system and will enable black-and-white pictures to be produced on monochrome receivers as well as colour pictures on colour receivers.

Whereas the earlier experimental transmissions were mainly concerned with problems of compatibility, one of the main objects of the new series will be the assessment of the quality and acceptability of the pictures produced by the complete chain of colour equipment from studio to colour receiver. The pictures will consist of "live" studio items, colour films, still pictures and test patterns originating from experimental colour television cameras and equipment at Alexandra Palace whence they will be transmitted to the Crystal Palace transmitter. The transmissions will be received at a number of selected points in the service area of the Crystal Palace station on colour receivers developed by the radio industry for these tests. They will also be received on black-and-white receivers, which will provide more information about compatibility.

These colour transmissions, which will take place on Mondays, Wednesdays and Fridays, starting at 11 p.m. and lasting about 40 minutes, are being made in co-operation with the industry and in agreement with the Television Advisory Committee which has been asked by the Postmaster General to report on the whole field of colour television.

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Ideas on the Screen

In the post-war period, much attention has been given in industry to new methods for the promulgation of the latest ideas and techniques developed as a result of modern research and the application of science. In this connection, it has been found that films can play a leading part; consequently, there has been a great increase in their use for industrial purposes, and the numbers available have grown enormously.

To provide a means of showing how films are being used in industry, and to give sponsors and producers an opportunity of evaluating such films and of studying the best productions from all over the world, it has been decided to hold a festival of industrial films at Harrogate in October next year. The President of the festival will be Lord Godber, the chairman of the Shell group of companies, which, for some time past, has been making and using industrial films on a large scale. The festival, which is stated to be the first function of its kind in this country to be devoted to industrial films, will be entitled "Films in the Service of Industry," and sponsors and producers of these films will be invited to enter leading examples of their work on a competitive basis, but the purely advertising types of films will not be eligible as the festival will not cater for these categories.

Preliminary arrangements are in the hands of a committee, under the chairmanship of Mr. Frank A. Hoare, which includes representatives of the Federation of British Industries, the Trades Union Congress, the Central Office of Information, the Association of Specialised Film Producers, the Scientific Film Association, and the Mayor and Corporation of Harrogate. The headquarters of the festival are at 3 Portman Chambers, 7-9 Baker-street, London, W.1 (Telephone: WELbeck 1104), and it is expected that further details and invitations to participate will be issued early in the new year.

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Further Progress in Steel Productivity

At a time when there is increasing talk of the participation by this country in a Western European customs union it is well to record the continuing progress in terms of productivity of one of Britain's most efficient industries. Between 1946 and the present time output per man-year in the steel industry has increased by 46 per cent. Since pre-war days the volume of output has more than doubled and productivity has gone up by as much as 66 per cent. Since 1947 the volume of output has risen by 71 per cent. while the labour force has gone up by only 17 per cent. Capital investment in modern steel works is now running at about £15,000 per worker.

It is this high rate of capital investment which has maintained the notable rise in efficiency in the industry over the last decade. In the latest issue of *Steel*, published by the British Iron and Steel Federation, outstanding examples of labour-saving investment are said to be the installation of high-capacity unloaders for ore at the docks and the new ore-carriers which have been designed for easy discharge; in recent years the unloading time for 6,000 tons of ore has dropped from 1,100 to 679 man-hours. There have also been significant advances at the blast furnaces: larger furnaces have resulted in larger tonnages of pig iron produced for a much less than proportionate increase in man-power. Similarly, there has been a 60 per cent. increase in the average annual output of open-hearth steel furnaces, with a corresponding increase in labour productivity. In steel-rolling, the change from reversing mills to continuous rolling mills has had an important effect and the gradual concentration of 75 per cent. of sheet and tinplate output at the three major continuous wide-strip mills at Ebbw Vale, Shotton and Margam has revolutionised this side of the industry. Technical changes, such as improved methods of ore preparation and oil burning, have also played an important part.

For the future, there is the likelihood of the increased practice of pre-preparation of raw materials at the blast furnaces and its extension to the steel mills. Beyond that again no doubt lies progress towards the continuous making of steel. The steel industry stands as a striking example of successful policy of high capital investment and of the virtues of "scrap-and-build."

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The Price of Copper

The decision of the Rhodesian Selection Trust to reduce the basic price of electrolytic wire bars to United Kingdom consumers from £300 to £280 per ton recognises that the recent weakness in copper prices on the London Metal Exchange is not merely a short-term fluctuation. Other world copper prices have also declined, except those charged by United States producers who are adhering to their price of 40 cents per pound, which is approximately equivalent to £320 per ton.

The fall in the London price appears to have been due mainly to expansion of world production. In spite of a decline in activity in some branches in the electrical engineering industry and, of course, in the motor industry, United Kingdom consumption of refined copper for the first eight months of 1956 stood at 321,500 tons, compared with 303,500 tons for the corresponding period of 1955. United States consumption of refined copper also rose from 771,900 short tons in the first six months of 1955 to 847,300 short tons in the corresponding period of 1956. World production of copper, however, has been increasing rapidly following the interruptions due to strikes in the latter part of 1955 and the early part of 1956. In Northern Rhodesia, for example, smelter production rose from 140,100 tons in the period January to June, 1955, to 190,900 tons in the first half of 1956.

A further factor affecting the London price has, of course, been the arrangements made for the sale of 36,000 tons of copper from the United Kingdom Government stockpile over the next five months. Unless there should be a recurrence of strikes in the major producing areas it is difficult to avoid the conclusion that the trend of copper prices is likely to continue downwards over the next few months, though this could, of course, be reversed if there were a significant rise in activity in the electrical engineering industry. There is perhaps most scope for such a rise in the lighter section of the industry, since the output of most domestic electric appliances fell by about one-third in the first six months of 1956. Although statistics are not yet available, there have recently been reports that the big decline in sales has been brought to a halt, but it may be some time yet before any considerable recovery takes place.

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Aluminium Comes to the City

For the first time since the Middle Ages the whole of this year's Lord Mayor's Show in London will be devoted to one single theme: aluminium. On November 9, when Sir Cullum Welch, the new Lord Mayor of London, rides in procession through the City to take the oath before the Lord Chief Justice and the Judges of the Queen's Bench Division at the Law Courts, he will be preceded by 19 floats depicting the aluminium industry in all its facets. The British Aluminium Company, Limited—which is mounting the pageant—will be making the most of the opportunity to put over to the general public the variety of ways in which the metal is used to-day.

Following a float alluding to the early pioneering by the aluminium industry of hydro-electric schemes in the Scottish highlands, just before the beginning of this century, there will come three floats symbolising aluminium's contribution to speed: the Fairey Delta 2 supersonic aircraft, holder of the world's air-speed record of 1,132 m.p.h.; Bluebird, in which Donald Campbell raised the world's water-speed record to over 225 m.p.h.; and a Le Mans Jaguar; these three will represent the metal's achievement in the air, on the sea and on the land. Road transport will follow next with an all-aluminium Routemaster and a fire-engine of embossed aluminium sheet. A ship's superstructure, building construction at home and in the tropics will be illustrated on the next floats, one of which will carry a West Indian band playing and singing a calypso specially composed for the occasion. Aluminium in and around the home will follow and the last float will point the future for the metal in the atomic age. The design of all 19 of the floats has been the work of Mr. Ronald Dickens, M.B.E.

Sponsorship by a section of industry of the Show—one of London's largest free entertainments—sets an interesting precedent. The British as a whole are probably less conscious of the part that industry plays in their economy than any other nationality and future recruitment will be best encouraged by awakening public opinion. Perhaps next year the iron and steel industry or a group representing cement and concrete may be prompted to take advantage of those other great national events that the public can watch free of charge—the Derby and the Boat Race.

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Politics in Swiss Industry

Switzerland is not only the land of tourism, precision engineering and cuckoo clocks. It is also the home of the Initiative and Referendum. Those who complain that there are too many bureaucrats involved in running British industry should consider the Swiss system. Under the Federal Constitution the central government has only limited powers. It must submit major changes in policy to a referendum—a vote of all electors carried out throughout the country. This is not all. Any citizen who believes that a particular matter should be put to the vote can start an Initiative. Provided enough signatures are obtained a vote must be taken.

This sort of direct democracy means that highly complicated economic problems are decided by people who are incapable of understanding them.

A particular example of this is the Hovag affair which was put to a referendum in May this year. Hovag, short for Holzverzucher A.G., is a chemical company operating in the Grisons Canton. During the war, Hovag received as a strategic measure a subsidy for producing synthetic petrol from wood. This was continued for 10 years after the war on the grounds that the Hovag factories provided employment in an otherwise underdeveloped canton. The company carried out a major reorganisation during this time and set up a number of subsidiary companies producing cellulose and manures. The new companies appeared to be flourishing but Hovag declared that its activities would collapse without the subsidy.

Last September, the Swiss National Council voted a further 28 million francs over a period of five years. A referendum was held and the proposal to extend the subsidy was defeated. Many voters favoured the subsidy simply as a means of giving employment in a backward area. Others were against supporting what was looked on as an inefficient firm. The issue was obscured by a group of industrialists offering to buy Hovag.

As an instrument of economic policy the referendum has three main weaknesses. Issues tend to be voted on for the wrong reasons. Secondly, it is only natural that people not personally concerned will simply vote against spending money. Thirdly, there are so many referendums that low polls are general. For this the men must take all the blame as women have no votes in Switzerland.

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Too Many Dutchmen

To-day the Netherlands, like Britain, have full-employment and are actually short of labour, but, behind this prosperity, the Dutch are facing a serious population problem. The figure is increasing at a rate that will take it from its present level of below 11 million to 14¼ million by 1981, giving a density of 1,143 persons per square mile. The result will be a tremendous strain on the economy. More houses, more roads, more industrial employment are all needed at the expense of agricultural land. Part of the solution can be seen in the reclamation of the Zuider Zee. But even this great scheme will do little to solve the very real problem of land shortage. Farms cannot be further split up. So, for the farmers' sons, farm workers and townspeople who want to become farmers themselves there is only one solution—emigration.

From 1950 to 1954 over 20,000 Dutchmen emigrated, on an average, each year. The most popular countries are those parts of the British Commonwealth which have no quota restrictions on immigrants. During the past 10 years, Canada has received 105,000, Australia 70,600, South Africa, 22,900 and New Zealand 13,000. Brazil has taken 3,000 and Argentina 900. In spite of quotas 26,000 Dutchmen have entered the United States.

The Government policy is to maintain emigration at a moderate level. Information is readily available for would-be emigrants, both from private organisations and the labour offices, and the Government contribution to the emigrant's passage money is based on the amount that he and his family have paid in income tax in the preceding year. Scales are arranged so that every emigrant pays some part of the cost involved. Everything is done to ensure that only families likely to succeed are allowed to emigrate.

In 1954 the working population of the Netherlands was 3 million, of whom 11,600 emigrated. In the same year the natural increase of the working population was 43,000. Experts believe that emigration on this level is necessary to ease the pressure on home resources and to keep the door open for a possible increase in the 1960's when the rise in the population will speed up. For the receiving countries a policy which provides such hard-working and reliable future citizens is extremely welcome.

A Pure Atmosphere

Not least among the many services rendered by the larger engineering institutions to the profession, and to industry generally, is that of organising conferences on subjects of outstanding importance and complexity. The conclusions reached as a result of these deliberations are frequently of benefit not only to the profession but, indeed, to the whole community.

One of the latest of these discussion meetings is to be a large-scale conference on "The Mechanical Engineer's Contribution to Clean Air," which will be sponsored by the Institution of Mechanical Engineers. It will be held at the Central Hall, Westminster, London, S.W.1, from February 19 to 21, 1957; the organising arrangements being in the hands of a committee acting under the chairmanship of Captain W. Gregson, R.N.R., M.Sc., a past President of the Institution. The general theme of the discussions will be that smoke and dirt spell inefficiency and that the recent Clean Air Act is designed not only to provide improved health conditions and more pleasing surroundings for the community to live and work in, but, automatically, to produce much greater efficiency in the use of fuel of all kinds.

The conference will be opened by the President of the Institution, Mr. T. A. Crowe, M.Sc., on the evening of February 19, and this will be followed by an introductory lecture, to be delivered by Sir Ewart Smith. In all, about fifteen papers (including some sub-divided into sections) will be discussed at morning and afternoon sessions on the two following days, and these papers have been arranged so as to cover the whole field designated by the title of the conference. The authors are all acknowledged specialists in their own spheres of activity and it is expected that the outcome of the meeting will be to clarify the actions which will be necessary to fulfil the requirements of the new Act. In order to obtain the widest possible coverage, a number of sister institutions and learned societies have been invited to take part, and, among others, it is hoped that members of the Institute of Fuel will make important contributions to the discussions.

Membership of the conference, for which a registration fee of £1 5*s*. will be payable, is open to interested persons generally, and they should apply, unless members of one of the other participating bodies, to the Institution of Mechanical Engineers, 1 Birdcage-walk, London, S.W.1. Advance copies of the papers will be on general sale at a cost of 15*s*. a set, if ordered before February 22; and, at a later date, bound volumes of proceedings will also be available.

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Computers to the Rescue

Describing the human brain as "this pinkish jelly" of so many limitations, an eminent physiologist set about to convince production engineers that the least they needed was some help from thinking machines. "Instruments to estimate as we do the pattern of favourable circumstances might not be more sensitive or more accurate than we, but the production engineers who would control their manufacture would surely see to it that they did not include in their designs the fears and prejudices which deflect our judgment and threaten to destroy our society." These were the closing words of the 1956 Viscount Nuffield Paper, "Thinking Machines," read before the Institution of Production Engineers in Bristol last week by Dr. W. Grey Walter who directs the Burden Neurological Institute.

Dr. Walter was concerned mainly with the imperfections of human reasoning, as revealed by experience and in latter years measured (if imperfectly) with the help of instruments developed during the war. Only a close study of Dr. Walter's paper can provide an adequate introduction to so complex a subject—"ten thousand million individual cells, all capable of continuous interaction with one another." He approaches his subject with due humility—"the study of machines designed to imitate some rudimentary features of human behaviour throws into glorious relief the variety and potentiality of human inheritance." Nevertheless Dr. Walter concludes that "the possibility of amplifying our reasoning powers with artificial thinking machines should not be rejected out of hand."

This most stimulating paper does indeed suggest that the creative ability of the human brain, or groups of brains, will produce machines that can greatly ease the task of plotting a course in the mass of confusing and conflicting facts and influences that surround us. Too many of us are unable to overcome the indolence and fatigue that bars the way to conscious exercise of our logical powers. Let us then use the machines we create to make life less of a gamble and to free those of us who can reason well and clearly (in Dr. Walter's view a tiny minority) from overload.

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N.U.R. Goes Ahead

The National Union of Railwaymen is to go ahead with its claim for a 10 per cent. increase in wages without the support of the Transport Salaried Staffs' Association. The Association, on its part, has decided that the time is not opportune to proceed with a claim, and so the N.U.R. is to go on alone, to catch up with the Associated Society of Locomotive Engineers and Firemen, whose claim on behalf of footplate men for a 15 per cent. increase in wages has already been turned down and has gone to arbitration.

Were the N.U.R. claim to be accepted it would cost the railways about £35 million a year. Before this demand gets to the critical stage, however, there are two others to be decided upon, both involving the British Transport Commission. The first is the A.S.L.E.F. claim already mentioned and the other is the claim by provincial bus drivers, which is also at the arbitration stage. A further complication is that, on the outcome of the provincial drivers' demand will depend the attitude of the London bus workers to higher wage demands on their own behalf. (The decision on the London busmen's claim for £1 a week pay increase was postponed after meetings lasting more than five hours on Monday, October 22, between the London Transport Executive and the Transport and General Workers' Union; the meetings were adjourned until a date which is yet to be announced.) Both these claims, of course, involve the Commission.

So far as the railways are concerned, revenue is still shrinking and the prospective deficit this year is about £45 million. It is quite impossible, therefore, for them to find out of revenue the money with which to pay higher wages. Any rises in wages which are granted to railway employees from now on must come out of a deficit, and this means that it will have to be paid out of the public purse. Railway workers are laying claim to be subsidised by the taxpayers. It is a proposition which is not likely to appeal either to the Commission or to the Government. Meanwhile, the other two claims are still to be dealt with and what happens in those cases will give some idea of the sort of opposition that the militant men of the N.U.R. are going to encounter.

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U.S. Car Boom Forecast

The American car manufacturers expect sales in 1957 to be at least 5 per cent. higher than this year. Some, including two of leading Ford executives, forecast a 10 per cent. increase. The general manager of Chevrolet agrees with the "often-published prediction of a total market of 6·5 million passenger cars in 1957," compared with an estimate of 6·2 million for 1956. This

confidence is reflected in the highest investment ever made in plant and tools. Ford spent more than 200 million dols., Chrysler 300 million dols. and the expenditure of the General Motors division is unlikely to be less than that of Ford and Chrysler combined. This means that the U.S. car industry is backing the forecasts of its market research teams to the tune of 1,000 million dols. or more. There is no sign anywhere that the fall in demand, which brought sales down from over six million cars in 1950 to 4 million in 1952, will be repeated in 1955 to 1957.

The industry's confidence is doubtless based on the elaborate research undertaken on a continuous basis by all leading manufacturers, and there is already evidence that the demand is rising. At the end of September—the last month of the 1956-model year—stocks at dealers were only about 350,000 cars, one of the lowest levels ever recorded. Production in the last quarter of the year is expected to reach 1·6 million and sales 1·4 million, so that stocks at the end of the year will be about 500,000, which is considered normal. In addition, used-car prices have been firm and sales good. The only factors which may adversely influence sales are rising prices and the shortage of steel. But the increase in Ford prices—averaging 2·9 per cent.—are lower than had been expected and unlikely to be high enough to affect demand. The shortage of cold-rolled strip on the other hand, expected to become acute towards the end of the year, may prevent manufacturers from reaching their objectives.

Manufacturers have probably produced more design changes, which include many new technical features than at any time since the war. The Italian influence on styling was in evidence at the Motor Show, but engineering changes—such as new automatic transmissions, fuel injection, new types of wheels and even new engines—have been made to tempt new car buyers. Detroit sales managers expect good returns on the capital investment that these changes represent. Other developments of interest are in the competitive position of Ford and General Motors. Ford's new models match those of General Motors car for car in the medium and higher price ranges. A hard struggle is likely but higher sales all-round seem assured.

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Indian Summer for American Shipbuilders

For the first time since 1953, shipbuilding orders with United States yards have reached £1 million. That fact should flash a warning to the other shipbuilding yards of the world that circumstances may not forever be to the disadvantage of the high-cost American shipbuilders. For the moment, the recovery in activity can be accounted for by the high level of demand for oil-tankers everywhere and the new United States Government regulations intended to stimulate the replacement of ships owned by United States shipowners who enjoy a Government subsidy. Out of 44 vessels under construction at the beginning of October as many as 32 were tankers, but the remaining 12 were a mixed collection of passenger ships and cargo vessels of various kinds.

There are two other significant developments in United States shipbuilding at the moment. Earlier this month, a converted United States Liberty ship arrived at Southampton from New Ycrk—the first large merchant vessel to be propelled solely by a gas-turbine and her bow has been lengthened as part of the exercise. She is part of an experiment by the United States Maritime Commission to find out if the 1,500 Liberty ships in reserve should be re-commissioned or scrapped. Another experimental Liberty ship goes on trial with gas-turbine propulsion in December. It is much too soon to say whether this experiment will be successful but if it were the threat of a large reserve cargo fleet hanging over world shipping would become very much intensified—a bogy which has been at rest for the last 10 years.

The second development in the United States is the official decision to design and build an atom-power merchant ship. This vessel will have its reactor supplied and installed by the Atomic Energy Commission, while the Maritime Administration in the Commerce Department will be responsible for the design and construction of the ship which has been specified to carry 100 passengers with a deadweight cargo capacity of 12,000 tons at a speed of 21 knots.

These various developments across the Atlantic do not suggest the imminent arrival of the United States shipbuilding industry as a major world competitor, but a combination of technical developments could bring this about while the rest of the world's shipyards were struggling to meet delivery dates with large orders for ships of conventional construction.

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Cross-Currents in Industry

In a statement at the annual banquet of the Society of Motor Manufacturers and Traders, Mr. Macmillan expressed his pleasure at the growing success of the Government's credit policy. He saw more flexibility in employment and business generally but pointed out that the pressure was " not that of the boa constrictor but of the masseur." Earlier Mr. Frank Perkins had accused the Government of " taking every possible step to downgrade the industry." Speaking at the opening of the Show, the Prime Minister had made clear that the Government " are not going to relax the battle against inflation until we know for certain that it has been won."

There is little that is ambiguous about such statements, yet, though the intention is clear enough, the ground for satisfaction is not so obvious. The Treasury expect that capital expenditure in manufacturing industry " may soon be levelling out, especially in 1957." This view—stated in the current issue of *Bulletin for Industry*—is supported by the drop in new factory building approvals for the first nine months of the year and in the net new home orders for machine tools. On the other hand, the *Bulletin* points out that new home orders for capital goods in engineering generally " seem to have been picking up " and may be above the 1955 level. Likewise the tide appears to be turning for manufacturers of durable consumer goods. The big decline in the sales of electric and gas domestic appliances has been halted and, although the total hire-purchase debt is still falling, there has been a sharp revival in new hire-purchase sales.

The general feeling is therefore that a new spurt in industrial activity is about to take place. Even in the motor industry there is an expectation of an increase in sales. Companies reporting last week generally confirm this upward turn in activity. Pressed Steel announce a lower interim dividend but comment that " there are definite signs of improvement in the motor-car industry." Atkinson Lorries (Holdings) Limited report a 16 per cent. increase in the number of vehicles delivered (for the year ending March 31) " as a result of a greater demand for heavier-class vehicles." The company, whose output has more than trebled since 1949, have extended their capacity and are proposing to extend it further: " we still retain our optimism and are supporting it by the purchase of a further 14 acre plot of land." Although their chairman, Mr. W. G. Allen, complains of the effect of purchase tax, hire purchase and credit restrictions, there is little evidence that these factors are interfering seriously with the rate of the company's expansion.

Signs that export demand for cars and commercial vehicles remains high are provided by the German production figures for September. Total output rose to 91,129 units, compared with 84,273 in the United Kingdom, and the export percentage from 43·1 per cent. in August to 45·3 per cent. The annual report of the Régie Nationale des Usines Renault for 1955 shows that increased output is not a prerogative of Germany. Nearly 223,000 vehicles were produced, an increase of 11 per cent. and exports rose by 35 per cent. Orders in hand are greater than ever before. The order for 3 million dollars booked by B.M.C. during the Motor Show suggests that the turn of the tide for the British industry is not far off.

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Development Plans

To publish a 10 year development plan is an unusual occurrence in British industry. Birlec Limited, a member of the A.E.I. Group, announced last week that they had purchased a 34 acre site for the building of a new factory to which they will eventually transfer all present activities. Already the largest manufacturers of industrial furnaces and equipment in the country, they plan to double their labour force by 1966.

James Howden and Company, Limited, whose main products are boiler plant auxiliaries, also announced expansion schemes and greatly increased order books. Their chairman, Mr. Crawford W. Hume, reports rapid progress " of scientific and technical developments in recent years " and comments that their research building, completed four years ago, has proved one of the company's major assets. All the Group's factories are in full production, including those of companies in South Africa, Australia and Canada, and the main problem remains the shortage of manpower.

Other companies reporting satisfactory results and improved order books are Sir Lindsay Parkinson and Company, the civil engineering and building contractors; Limit Engineering Limited, makers of small electric motors and ancillary equipment; Parsons' Marine Turbine Company, Limited; the Neepsend Steel and Tool Corporation, and Westland Aircraft Limited (controlled by John Brown and Company). Neepsend's chairman, Sir Stuart Goodwin, announced the broadening of the company's activities by the acquisition of three businesses and comments that " for the first six months of the current financial year, output has been fully maintained despite the recession in the motor industry." Mr. R. Cyril Thompson, chairman of Parsons' Marine, pointed out that a reduction in the company's capital expenditure was " only of a temporary nature," and that " Plans for modernisation of the gear-cutting equipment are under active preparation, and new machines for the other shops have been ordered since June 30, 1956, while the purchase of further new machines is under consideration."

Mr. Eric Mensforth, chairman of Westland, reports a major rise in profits—by over 80 per cent.—and a very active demand for the company's helicopters. Their expanding programme " has necessitated a considerable increase in production facilities " and the additional space required " also enabled extensive re-arrangements and improvements to be carried out." Westland's subsidiary, Normalair Limited, who specialise in the supply of complete systems for pressurising and air conditioning high-flying civil and military aircraft, also had a good year, but fear that the impending reductions in defence expenditure will create a big gap which they may find difficult to fill quickly from sales to other markets.

The fireworks were provided by Mr. C. O. Stanley, chairman of Pye Limited. Commenting on the erection of a large new factory (100,000 sq. ft. employing over 1,000 people) at Larne, Antrim, he said that Pye had had in mind the threat of nationalisation of the electrical goods industry should the Socialists come to power. They have created a separate capital structure for the new factory—the Corran Works—which would enable them " at a moment's notice, if nationalisation became an imminent threat, to turn the Corran Works over to a company controlled in the north of Ireland and, consequently, outside the sphere of nationalisation." Symptomatic, perhaps, of Labour's progress and Mr. Bevan's advance.

ENGINEERING CONTRACTS

7—AVAILABILITY OF PLANT AND MATERIALS

By F. H. B. Layfield

This is the seventh article of the series being contributed by Mr. Layfield for the guidance of engineers and others engaged on the preparation of engineering contracts. The sixth article appeared in ENGINEERING, *October* 12, 1956, *page* 457.

The engineer's main interest in an engineering contract is to see that matters are so arranged as to secure the prompt and proper completion of the works concerned. He wants to be able to get the job done come wind, come weather. It follows that he will wish to anticipate what may occur should the contractor, for one reason or another, prove unable to complete the works once having started them. The most likely occasions on which such an eventuality might arise are twofold; the contractor may prove incompetent or inefficient, on the one hand, or, on the other, he may become so short of money that he is unable to carry on. In the latter instance the contractor may often go bankrupt. These possibilities often seem remote at the time when the contract is prepared; indeed, it is unlikely that the engineer would encourage the employer to enter a contract at all if such eventualities did seem likely to occur. Yet it would be an unwise man who failed to make provision for just such contingencies, especially when the contract works are to be on any considerable scale.

If the contractor proves unable to carry on, the engineer will usually have one main practical interest at that time. He will wish to see that the plant and materials necessary to execute the work shall remain on the site, as this will enable another contractor to be employed, and thus ensure speedy completion. If such an object is to be achieved two matters need particular attention. In the first place, the plant and materials must be freely available for the use of the incoming contractor; if the engineer is to make such plant and materials available then it is desirable that they should, at any rate for the time being, be regarded as the employer's property. Secondly, the property concerned must be free, not only from the defaulting contractor's claims to possess and use it, but, and far more important, the property should be protected against the claims of the defaulting contractor's creditors, liquidator or trustee in bankruptcy.

BUILT-IN MATERIALS

So far as materials or equipment which are built into the land are concerned there is usually no difficulty. Under all normal circumstances, whenever a contractor has brought materials on to the site *and* affixed them to the soil, or to the buildings or erections regarded as forming part of the land, then those materials are no longer the contractor's property, but become the property of the building owner. However, materials and plant brought on to the site by the contractor remain his property until such time as they are so affixed to the land, unless there is a provision in the contract to the contrary.

It is natural, therefore, to attach much importance to provision in the contract which will make plant and materials brought on to the site become the property of the employer. It should, perhaps, be added that once materials have been affixed the contractor cannot remove them even if the employer has later severed them and they are no longer fixed, unless the contractor has an express contractual right to do so.

Sometimes a contract provides that payment shall be made for materials or plant delivered as soon as those items are included in an interim certificate. If this be the case, it is likely that the property in those materials passes to the employer so soon as the relevant certificate is made. As, however, the position in this connection is not entirely certain, it may be wise to make the time of transfer of property clear in the contract documents.

PROPERTY VESTED IN EMPLOYER

What is often needed is a clause in the contract which will provide that materials and plant belonging to the contractor shall, when they are brought on to the site, thereby become the property of the employer. The Courts have directed attention to the care with which such clauses must be drawn; some words effectively achieve the purpose in hand while others may not. Thus, Lord Reid, speaking in the Judicial Committee of the Privy Council, has said:

> " A distinction has been drawn between clauses which provide that as and when plant or materials are brought to the site they shall be ' considered ' or ' deemed ' to become the property of the building owner, and, on the other hand, clauses which provide that they are to ' be and become ' his property. In the former case, it has sometimes been held that the clause was ineffective to achieve its aim and that the property remained in the builder and at the mercy of his creditors and trustee in bankruptcy."

It would seem to follow from judicial pronouncements such as Lord Reid's that the course of wisdom is to eschew the use of such phrases as " considered " or " deemed " and to state in the contract that the particular items concerned shall " be and become " the property of the employer, or to use some closely similar phrase.

Lord Reid's observations should be borne in mind whenever the Institution of Civil Engineers' General Conditions are used. In clause 53 (2) of that document, it is provided that certain plant of the contractors, when brought on to the site, shall " be deemed to become the property of the employer." It is not by any means certain that the expression " deemed," is ineffective for transferring property in this regard, but the wiser course will be to avoid its use. An instance of clear and unambiguous wording occurs in the standard form " A " prepared by the Joint Committee of the Institutions of Mechanical, Electrical and Consulting Engineers. Clause 17 of that form provides, among other things, that

> " Plant supplied pursuant to the contract shall become the property of the purchaser at whichever is the earlier of the following times, namely (*a*) when the plant is delivered pursuant to the contract, (*b*) when . . . the contractor becomes entitled to require that the value of the plant be included in an interim certificate."

It should be observed that this form of contract so defines the word " plant " that it " shall mean and include machinery, apparatus, materials, articles and things of all kinds."

RIGHTS IN UNUSED MATERIALS

If the contract contains a clause vesting plant and materials on the site in the employer, there will normally be an implied right on the part of the contractor not only to use them for the purposes of the contract but also to reclaim unused materials and plant upon the completion of the contract works, but though this implied right exists it is desirable to have an express provision dealing with it. Such arrangements do not, however, dispose of all of the engineer's problems. The normal vesting clause, with its implication of the right of the contractor to reclaim plant and materials on completion of the works, should, if properly drawn, deal with a case where the contractor defaults or goes bankrupt. The usual contract which contains such a clause leaves the situation in another eventuality in some doubt. It sometimes happens that the contractor terminates the contract before the work is ended, alleging, correctly or incorrectly, that the contract has been avoided or ended by reason of the employer's or engineer's default. When such a situation arises and the contractor refuses to continue, the engineer will usually be as keen to complete the work as in any other circumstances. It follows that it may be desirable to make clear and explicit in the contract what is to happen to plant and materials on the site in cases where the contractor, or indeed the employer, terminates the contract on the grounds that the contract has been avoided by the other party.

EFFECTS OF HIRE AND HIRE-PURCHASE

Nowadays, the degree of specialisation which equipment has reached and the heavy cost of plant, among other reasons, have led to the fairly extensive use of hiring facilities. As a result, the contractor may bring on to the site plant and equipment which is not his own for use on the contract works. As that plant is not the contractor's own, the normal clause which vests plant in the employer does not affect this particular plant. On the other hand, highly-specialised hired plant may often be the very thing which the engineer most desires to retain on the site should the contractor default. Such a position raises very troublesome issues. These difficulties arise largely because the owner of the hired plant has no contractual relationship with the employer. There is, of course, no question, under normal circumstances, of property in hired plant passing to the employer. The best that can be done is to endeavour to give the employer the right to step into the shoes of the contractor as hirer, should the contractor default. The Institution of Civil Engineers' General Conditions try to achieve this result by requiring, in clause 53 (3), that the contractor shall not bring on to the site any vital plant which has been hired, except under certain conditions. The most important of these conditions is that which requires that the agreement for hire shall contain a stipulation that the plant owner shall, on receipt of certain notices to be given in the event of the contractor's default, transfer the hire of the plant to the employer on the same terms and conditions as pertained to the contractor's hiring.

It is doubtful, however, if these provisions could be enforced by the employer. Assuming that the contractor does see that the requisite terms are included in his contract with the plant owner, then it is true that the *contractor* could insist on his right to transfer the hire to the employer. Yet, in the natue of the event, if the contractor has defaulted, or gone bankrupt, it is at least possible that he will make no very great exertions to prevent the plant owner resuming control of the plant should the latter so desire. The employer himself would probably be unable to insist on the fulfilment of the terms of the hiring contract because of his not being a party to that contract. Of course, it may often be that the plant owner will be entirely content to allow the employer to step into the contractor's shoes, should the latter default. That fact should not, however, obscure the danger that, where the plant owner proves unco-operative, the employer's position is a weak one. Perhaps the only really safe course is either to require that the employer shall himself be a party to the hiring agreement, thus giving him some legal standing in the matter, or, alternatively, to make the employer the nominal hirer of the requisite plant.

Very much the same difficulties apply to the use of hire-purchase plant on site as to use of hired plant. Here again, if the contractor defaults, the engineer may be in an unwelcome situation. Contracts often state that, in order to avoid seizure by the owner of any hire purchase plant, the employer shall " be entitled to pay such owner the amount of any overdue instalment or other sum payable under any agreement for hire purchase." This is normally accompanied by

provision for the recovery of any such sum actually paid by the employer. The difficulty is that, as with hired plant, although this provision is plainly enforceable against the contractor, it is by no means certain that it is enforceable against the plant owner. Once more, the only real remedy probably lies in direct relationships of one kind or another between the employer and the plant owner.

In any event, it is desirable to include in the contract a clause requiring a return to be made to the engineer, detailing the position with regard to hired and hire-purchased plant, which the contractor has on the site. This is done in the Institution of Civil Engineers' General Conditions, but that document only requires the return to be made "upon request made by the engineer at any time." Engineers may sometimes feel that it is wise, while retaining their right to make such inquiry at any time, to stipulate that a periodic return should be made at stated times. Clearly there are contracts where the circumstances are such that the engineer will wish to watch most carefully the quantity and nature of hired and hire-purchased plant in use on the site, remembering always the weakness of the employer's position in regard to his control of such plant.

SUMMARY

Few people imagine, at the time when they enter a contract, that the other party will default or for any reason leave his part of the contract work unfinished. Yet, in practice, default or bankruptcy happens sufficiently often to make it something which should be anticipated when the contract is drawn up. If default or bankruptcy does occur, it poses a host of legal problems for the employer and his advisers, but the engineer's chief concern at such a juncture will usually be to finish the work. If this is to be done, it is important that the plant and materials on the site should be available at once for another contractor to use and so carry on the work. So far as fixed materials are concerned there is no problem. Provision must, however, be made for the possession of *loose* materials and plant to vest in the employer, either from the moment they come on to the site, or so soon as their value is included in an interim certificate, whichever be the earlier.

It is not so easy to make effective provisions for the retention by the employer, on the contractor's default, of plant which was never the contractor's own. Nevertheless, efforts must be made to secure, where such plant is on site, that it can be retained by the employer for use on the work, but, unless the employer is in direct contractual relationship with the real owner of the plant, such arrangements may prove of little value if the plant owner is unhelpful.

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POWER FOR THE COPPERBELT

An important electric power link-up has now been put into operation between Northern Rhodesia and the Belgian Congo. Power is now being imported to the Copperbelt from Le Marinel hydro-electric power station on the Lualaba river in the Congo. The formal announcement by the Rhodesia Congo Border Power Corporation marks the completion of a scheme which has had the benefit of an £8-million credit from the Export-Import Bank in Washington.

The immediate significance of the link-up is that power will be available to the copper-mining companies in addition to that generated by their own thermal stations. It will alleviate to some extent the coal shortage which is a chronic problem for the mining industry in Northern Rhodesia. The importation of power will not, of course, make the transportation of large tonnages of Wankie coal any the less urgent but it will close part of the fuel gap and will act as a short-term source of power until the Kariba project is completed. It is estimated that the present peak load demand in the Copperbelt is about 165 MW but that this will increase to about 250 MW by 1960.

ECONOMIC LOT SIZE IN BATCH PRODUCTION

MAXIMUM RATE OF RETURN ON CAPITAL INVESTED

By Samuel Eilon, PH.D., DIPL.ING., B.SC.(ENG.), A.M.I.PROD.E.

In this paper, which is a sequel to one entitled "Quantities in Batch Production," published in ENGINEERING *on page 298 of the issue of September 7, 1956, the differences between the economic lot size and the minimum-cost lot size are summarised. Conventional methods for computing the economic lot size are discussed and a new approach is described. A formula for finding the ratio of economic lot size to minimum cost lot size is suggested and the effect of the ratio of constant costs per piece to preparation costs per piece is analysed.*

Notation

B	Average storage costs per piece per unit time	i	Interest rate per unit time (expressed decimally)
I	Carrying costs per piece per unit time $= i\,c$	p	A ratio $= \frac{Y-c}{Y_m-c}$
I_e	Carrying charges per piece per unit time $= (i+r)\,c$	p'	A ratio $= \frac{Y'-c}{Y_m-c}$
K	Carrying-costs factor	q	The ratio of economic lot size to minimum-cost lot size $= \frac{Q_e}{Q_m}$
Q	Quantity produced	r	Additional interest rate regarded as the proper return on the capital (expressed in the same manner as i)
Q_e	Economic lot size	s	Preparation costs, including machine set-up
Q_m	Minimum-cost lot size	u	A ratio $= \frac{c}{\left(\frac{s}{Q_m}\right)}$
R	Rate of return on investment	γ	A ratio $= \frac{a_c}{a_p}$
T_c	Consumption period		
Y	Total costs per piece		
Y_m	Minimum costs per piece		
Y′	Sales price		
a_c	Consumption rate, units per unit time		
a_p	Production rate, units per unit time		
c	Constant costs per piece (materials, labour and overheads)		

Minimum-Cost and Economic Lot Sizes

The selection of lot size in batch production may have a decisive effect on the production costs, on the production schedule and on the profits of the firm concerned. Very often a lot size corresponding to minimum production costs per piece is aimed at (Q_m). Several formulae have been suggested for estimating Q_m, some of which may be expressed in the form

$$Q_m = \sqrt{\frac{s}{K}}. \qquad . \quad . \quad (1)$$

The factor K is the carrying-costs coefficient (the carrying costs being K Q per piece) and depends on many factors involved in the production procedure. One approximation which has been suggested[3] for the evaluation of K is

$$K = \frac{I\,(1+\gamma)+2B}{2\,a_c}. \qquad . \quad (2)$$

The selection of Q_m as the lot size may be fully justified in circumstances where production costs must be kept as low as possible. However, it was pointed out by F. E. Raymond and P. T. Norton[1, 2] that it is possible to produce a quantity Q_e smaller than Q_m, which will incur higher production costs per piece than those corresponding to Q_m, but which will be more profitable, because a higher rate of return on the capital invested is attained. It has been suggested[4, 5] that Q_e may be evaluated by

$$Q_e = \sqrt{\frac{s}{K_e}}. \qquad . \quad . \quad (3)$$

where K_e is given by a similar expression to (2), with I_e substituted for I, so that

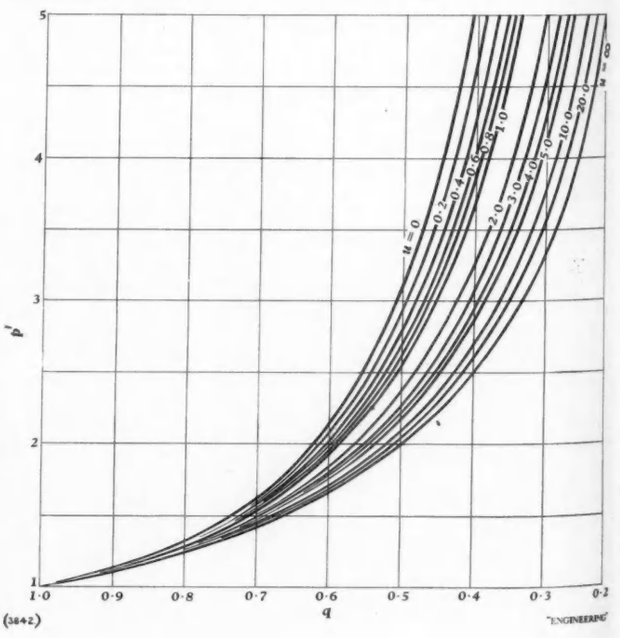
$$I_e = (i+r)\,c.$$

It is assumed in this method, (*a*) that the preparation costs are small and the rate of return is therefore related only to money invested in the constant production costs *c*, and (*b*) that the producer is free to select a desired value of rate of return and fix his selling price accordingly. In the majority of cases in industry both assumptions may not be true. Selling prices may be determined by conditions prevailing in the market, either due to competition or to preparedness on the part of the consumer to pay what to him seems a reasonable amount for the product. A different approach is required in such circumstances to determine the appropriate quantity Q_e.

Economic Lot Size

The most economic lot size is the one which provides maximum rate of return on the capital invested, or maximum ratio of profit to capital invested per unit time. The rate of return R can be expressed as

$$R = \frac{Q\,Y' - Q\,Y}{Q\,Y}\,\frac{1}{T_c}. \qquad . \quad (4)$$



In batch production it is possible to fix the lot size so that, although higher production costs per piece are incurred than in the case of minimum-cost lot size, the total return on capital invested will be greater. This economic lot size may be found from a chart in which a ratio p' is plotted against a ratio q.

It has been assumed here that all the investment is made at the beginning, and income is available at the end of the cycle period T_c. In fact, capital is tied at the beginning for materials and set-up costs, while wages for labour are being paid during the production period and income is available while sales are going on during the consumption period. The real rate of return will, therefore, be higher than the above by a factor which can be calculated according to the prevailing circumstances.

The maximum rate of return will occur when

$$\frac{dR}{dQ} = 0$$

or, if $T_c = \frac{Q}{a_c}$ is substituted, when

$$Y' \frac{d(YQ)}{dQ} = Y^2 \quad . \quad . \quad (5)$$

The function, costs per piece in terms of the quantity produced, is given by

$$Y = c + \frac{s}{Q} + KQ. \quad . \quad (6)$$

If this expression is substituted, the following equation for the economic lot size is obtained:

$$K^2Q_e^4 - 2K(Y' - c)Q_e^3 + (c^2 + 2sK - Y'c)Q_e^2 + 2csQ_e + s^2 = 0. \quad (7)$$

It can be shown that the economic lot size, which ensures maximum rate of return, is smaller than Q_m.* The above equation can be expressed in a simpler form by the use of (1) and the following definitions:

$$\left.\begin{aligned} p' &= \frac{Y' - c}{Y_m - c} \\ \text{or } Y' - c &= p'(Y_m - c) = p' 2KQ_m \\ q &= \frac{Q_e}{Q_m} \end{aligned}\right\} \quad (8)$$

where Y_m is the minimum total manufacturing costs per piece (achieved when Q_m is produced).

Hence

$$q^4 - 4p'q^3 + 2\left(1 - \frac{c}{\left(\frac{s}{Q_m}\right)}p'\right)q^2 + 2\frac{c}{\left(\frac{s}{Q_m}\right)}q + 1 = 0 \quad . \quad . \quad . \quad . \quad (9)$$

The expression $\frac{c}{\left(\frac{s}{Q_m}\right)}$ is the ratio of the constant costs per piece (materials, labour, overheads) to the preparation costs per piece, when the minimum-cost lot size is selected. This ratio, denoted by u, can be determined for any specific case. Thus

$$q^4 - 4p'q^3 + 2q^2 + 2uq(1 - p'q) + 1 = 0 \quad . \quad . \quad . \quad (9a)$$

or

$$p' = \frac{2}{2q + u}\left[\left(\frac{q^2 + 1}{2q}\right)^2 + \frac{u}{2q}\right] \quad (9b)$$

* This can be done by substituting in (5)

$$\frac{d(YQ)}{dQ} = c + 2KQ = Y - \left(\frac{s}{Q} - KQ\right)$$

Thus $$Y'\left(1 - \frac{\frac{s}{Q_e} - KQ_e}{Y}\right) = Y$$

Since $Y' > Y$

Therefore $\frac{s}{Q_e} > KQ_e$

From (1) and (6) it is evident that at the point of minimum costs

$$\frac{s}{Q_m} = KQ_m$$

while $\frac{s}{Q} < KQ$ for $Q > Q_m$

and $\frac{s}{Q} > KQ$ for $Q < Q_m$

If similarly to (8) a ratio p of variable costs is defined as

$$p = \frac{Y - c}{Y_m - c} \quad . \quad . \quad (8a)$$

it can be shown that

$$p = \tfrac{1}{2}\left(q + \frac{1}{q}\right) = \frac{q^2 + 1}{2q} \quad . \quad . \quad (8b)$$

This expression can be substituted in (9b), so that

$$2p'q^2 + (p'u - 2p^2)q - u = 0 \quad (10)$$

The advantage of this form over (9a) is that the quadratic equation is simpler to solve, when all the other factors are known. Admittedly, p in this equation is a function of q, but for comparatively high values of q the costs per piece do not increase very much near the minimum point on the Y curve, as given by (6).* In such circumstances it may be assumed that $p = 1$, and the value of q can be computed from the equation

$$2p'q^2 + (p'u - 2)q - u = 0 \quad (11)$$

where p' and u are known. The error introduced by the above assumption increases as u decreases, but even in the extreme case when $u \to 0$ the error is small, provided high values of q are involved. For $u \to 0$, expression (10) yields

$$q = \frac{p^2}{p'} \quad . \quad . \quad . \quad (12)$$

as compared with

$$q = \frac{1}{p'} \quad . \quad . \quad . \quad (12a)$$

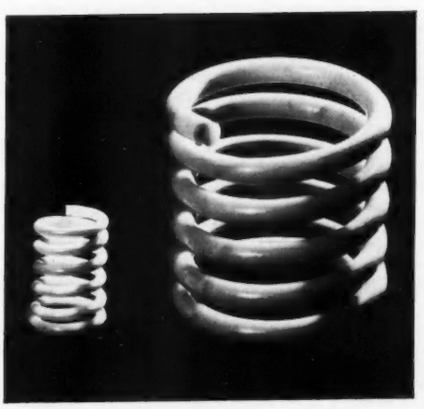
obtained from (11). If, for example, $p' = 1{\cdot}4$, the value of q computed from (12) is $0{\cdot}766$, whereas if the approximation (12*a*) is used, the value obtained is $0{\cdot}714$, the error being only 6·8 per cent. In practice if the constant costs per piece c are not negligible when compared with the preparation costs per piece (that is $u \neq 0$), the error introduced by assuming $p = 1$ is even smaller than the above. The error decreases further when higher values of q are expected.

However, when lower values of q (that is higher values of p') are involved, the error increases very rapidly and the approximation (11) is no longer adequate.

General Solutions

A chart with solutions to the general expression (9*a*) is presented on page 522 for various values of u. The ratio q can be readily determined from this chart, when the values of p' and u are known. The curves lie between two limits: one where $u = 0$ (that is when $p'q = p^2$), and the other where $u = \infty$ (that is when $p'q = 1$); all start at the same point ($q = 1{\cdot}0$; $p' = 1{\cdot}0$), thereby showing how manufacturers are compelled to produce minimum-cost quantities when competition is severe and when selling prices are comparatively low. The role of u is insignificant in this region, but becomes more and more important as the selling price, compared with production costs, increases. Another obvious conclusion is that when preparation costs can be reduced, a smaller amount may be scheduled for production, both because by (1) the absolute value of Q_m decreases and because the ratio u increases, thus resulting in a smaller value of q.

* If, for example, the economic lot size is 20 per cent. below the minimum-cost lot size, that is when $q = 0{\cdot}8$, the value of p is $1{\cdot}025$.



A Fluon self-lubricating and non-absorbent coating on metal springs renders them impervious to corrosive attack.

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[3] Eilon, S. "Quantities in Batch Production," ENGINEERING, vol. 182, page 298, 1956).

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MAGNESIUM PRODUCTION IN THE U.K.

It has been recently announced that a magnesium-zinc-zirconium alloy, ZRE1, containing also rare-earth metals, is to be used in the castings for the British space rockets which are to be launched during the coming International Geophysical Year. The castings have been manufactured by Magnesium Elektron Limited, Clifton Junction, Manchester, a pioneer firm of the British magnesium industry and to-day the sole producer of virgin magnesium in this country.

At the Clifton Junction Works, magnesium is produced by the electrolysis of magnesium chloride, the raw metal being then melted down, refined and alloyed.

Owing to the high cost of the electricity and the materials utilised, the electrolytic process is now uneconomic. The company is, therefore, studying other methods of extracting magnesium, and one method in which it has great hopes is the reduction, at high temperature and under vacuum, of briquettes made of calcined dolomite and ferrosilicon. The magnesium metal is liberated as vapour and condensed to crystal metal on the cool end of the retorts employed. Dolomite is a material which occurs extensively in this country and a pilot plant operating this process is at work at Clifton Junction.

During 1955, some 1,500 tons of magnesium were produced in the United Kingdom (all of it at Clifton Junction), while sales of the metal and of its alloys reached a total of 11,000 tons in the same year, this being made possible by imports of magnesium.

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IMPERVIOUS COATING FOR SPRINGS

An interesting development introduced recently by Crane Packing Limited, Slough, Buckinghamshire, a pioneer firm in the processing and fabrication of the plastic polymer, CF2-Polytetrafluoroethylene, has been the application of dispersion coatings of the polymer which is generally known as PTFE, or "Fluon." The dispersion coatings are obtained by applying to articles a milky-white liquid consisting of very small particles of PTFE resin suspended in water.

As will be seen in the accompanying illustration, metal springs can now be coated with Fluon and this renders them entirely impervious to attack by corrosive substances at temperatures ranging from − 50 deg. F. to + 450 deg. F., with the exceptions of the gas fluorine, and molten sodium. The coating also possesses the other properties of the polymer. It is unaffected by any known solvent; deterioration when exposed to the weather for long periods is negligible; it has high dielectric strength and is non-inflammable and non-absorbent. It is also "self-lubricating" and is non-adhesive.

Book Reviews

PRODUCT DRAWINGS

Drawings and Dimensions. By S. PARKER. *Sir Isaac Pitman and Sons, Limited, Pitman House, Parker-street, Kingsway, London, W.C.*2. (35*s.*)

Drawing is the engineer's language, his only medium of transfer from thought to material, and, like other means of expression, should be lucid and unambiguous, conveying its meaning in the simplest and most direct manner. As the author points out, there are many kinds of drawing in engineering work, each of which has its own place, from the rough sketches outlining an idea to the highly developed cut-away perspective views of, say, aeroplanes or motor-car components (illustrative drawings), or detail drawings as issued for manufacture. This book deals with the last, which the author calls product drawings. Such drawings determine the quality of the product in a permissive sense that if they are right the product may also be right, but, if they are not, it certainly will not be.

Good drawing, however good it may be, can never turn a bad design into a good one, but a good design may be spoiled, and endless difficulties and expense caused in development, use, and manufacture, by lack of clarity in the drawing stage. The main object of the book is to prevent this. A foreword by Dr. F. H. Rolt provides the background: the work of the author as Admiralty representative on committees dealing with dimensional analysis, inspection, and drawing office practice, and the book may be considered as an appendix to British Standard 308, "Engineering Drawing Practice." It is based on wide practical experience, particularly in inspection, where any weaknesses in dimensioning stand out vividly. A preface by the author explains this background work more fully and gives acknowledgements to fellow workers in that field.

The introductory chapter, which follows, is of the greatest importance, particularly such points as the development of experimental models, and the validity of manufacture and performance of a small batch as a criterion of the suitability of the drawings for quantity production. Chapters follow on drawing projection systems, conventions used, scales of drawings, and shapes and dimensions of engineering products; the main subject—how drawings should be dimensioned in order to help manufacture and inspection—forms the bulk of the book, in 19 chapters. The emphasis throughout is rightly on inspection and measurement, as, unless the drawing helps in these respects, there is no certainty as to real dimensions. The point is made that, although two similar components *may* be identical, there is no means of proving that they are so. Tolerances and limits naturally bulk largely in a book on quantity production, and the actual drawing becomes merely a frame on which to hang the figured dimensions. Special forms, such as gear teeth, screw threads, or springs, are not dealt with; they usually need special facilities for measurement, but the principles on which the book is based can be extended to cover them.

The word "drawing," as used, includes everything on the sheet, both figures and drawing; and the word "designer" is used in an omnibus sense of all those responsible for any of the information, pictorial and otherwise, shown on the drawing. Though the designer must specify exactly what he wants, he should not attempt to lay down how it is to be produced. Anyone familiar with the delays, frustrations and losses which result from lack of quality in the design and drawing stages will welcome any book which is really helpful in these matters, as this book certainly is. Engineering design is a very contentious subject and there are many conflicting views, which the author tries to resolve on a logical basis.

Drawings of items only made in limited numbers do not demand quite the same care, though even here, tolerances and limits have to be considered somewhere, and the drawing or design office is clearly the right place. "If the designer cannot specify just what is wanted in these matters he is no designer."

The whole problem is approached from the commonsense—but by no means universal—point of view that the drawing is rarely, if ever, an end in itself. It is a step towards the manufacture, assembly, testing, etc., of the hardware and every phase of the work must be done with this in mind. Other types of drawings, the illustrative or the pictorial, may be ends in themselves, but this book deals only with the last stage of the transfer from ideas to ironmongery, perhaps the most difficult. Although much of the matter is of an elementary nature it could not well have been omitted, and to cover the whole of dimensioning would hardly have been possible. Within its field—the dimensioning of engineering drawings so that the product can be readily produced, and checked and measured in the most effective way—the book can be thoroughly recommended, both on its own account and as a useful supplement to British Standard No. 308.

★ ★ ★

NEW BOOKS

Some of the books noticed here are selected for extended review in ENGINEERING.

The Analysis of Right Bridge Decks Subjected to Abnormal Loading. By P. B. MORICE and G. LITTLE. *Cement and Concrete Association, 52 Grosvenor-gardens, London S.W.*1. (Gratis.)

With the increase in the incidence and magnitude of heavy indivisible loads moving over our roads, it has become increasingly important to have a reliable method of analysing this effect on bridge decking. On the basis of work done at the Cement and Concrete Association's Laboratory at Wexham Springs, the authors have derived a method, using distribution coefficients, which is described in the booklet with the aid of worked examples. The various design charts produced in the book are available separately on such a scale as to make them of value in the design office.

The A.S.E.E. Guide to the Thirteenth Edition of the I.E.E. Regulations for the Electrical Equipment of Buildings, 1955. *The Association of Supervising Electrical Engineers, 23 Bloomsbury-square, London, W.C.*1. (5*s.*)

When the twelfth edition of the I.E.E. Regulations was published, the Association of Supervising Electrical Engineers issued a guide in simple language with explanatory diagrams for the use of students, supervisors, technicians and operatives. This enterprise was so successful that it has been followed by a similar guide to the thirteenth edition. In general, this follows the same plan as its predecessors. Where the regulations are quoted, the numbers and exact wording are used; points of special interest being emphasised by underlining. Explanations and rewording of the regulations and definitions, for which the Association is solely responsible, are printed in heavy type. A cross-reference index has been provided to facilitate the relation of the twelfth to the thirteenth editions and thus aid those who associate a particular regulation with a particular problem.

High Voltage Impulse Testing. Notes on Applied Science No. 17. Published for the Department of Scientific and Industrial Research by *H.M. Stationery Office, Kingsway, London, W.C.*2. (1*s.* 6*d.*)

When lightning strikes overhead electric power transmission lines it gives rise to impulse voltages, and to guard against these the equipment must be provided with high insulation properties. As a result, impulse testing has become essential, and this booklet gives an account of the experiences which have been gained in the High Voltage Laboratory of the National Physical Laboratory in this field, during the past 20 years. The effects of lightning strokes on transmission systems are described, including the effects of strokes which strike not only the conductors, but also the towers, the earth line and even the neighbouring ground. In all these cases, it is pointed out, surges can be set up in the transmission lines. The production of test impulses in the laboratory, the creation of standard wave shapes and the making of test measurements are dealt with, and the methods of testing insulators, protective gaps, cables, transformers and capacitors are described.

The Crypton Course of Engine and Electrical Servicing: A Complete Course in the Principles and Practice of Automobile Engines and Electrical Testing and Diagnosis. *Crypton Equipment, Limited, Bridgwater, Somerset.* (42*s.*)

Designed for the instruction of service mechanics, this guide, which is in loose-leaf form, is written from the practical angle. An examination paper is provided for each of the 12 lessons, six of which deal with the electrical system and six with the mechanical. Detailed diagrams are included for each lesson.

Tell the People. By MIKE WILLIAMS-THOMPSON. *World's Press News Publishing Company, Limited, 9–10 Old Bailey, London, E.C.*4. (12*s.* 6*d.*) (See Plain Words in our issue of October 5, page 418.)

La Thermodynamique et le Théorème de l'Énergie Utilisable. By R. MARCHAL. *Dunod, 92 Rue Bonaparte, Paris, 6e.* (1,580 francs.)

This book is a summary of lectures delivered by the author to students at the Ecole Nationale du Génie; the object being to facilitate the comprehension of the way in which thermal machines of different types operate. It may be regarded as based on the thesis that thermodynamics is difficult to understand owing to its abstract nature. To escape such obstacles as those involved, for instance, in a discussion of entropy it is, therefore, tempting to take refuge in the abstract and to adopt a mathematical treatment which, while apparently dealing with actual problems, results in hiding all the difficulties. The treatment employed by M. Marchal is straightforward and, as mathematics are not so predominant as is usual in French text-books, it is hoped it will appeal to a wide circle of readers.

★ ★ ★

TRADE PUBLICATIONS

Copies of any of the following trade publications are obtainable from the addresses given, though distribution is sometimes restricted.

Aluminium for Transmission Lines. ALUMINIUM UNION, LTD., The Adelphi, John Adam-street, London, W.C.2. Descriptions of methods of selecting and installing base aluminium stranded and steel-cored aluminium conductors for transmission and distribution lines. The data presented describes lines operating at voltages from 6·6 to 230 kV. Data is given regarding various types of conductors and their available sizes. The advantages of aluminium for the transmission lines, the available sizes of conductors, line calculations, current carrying capacity, loading conditions, erection practices and accessories are among the other subjects dealt with. Illustrated booklet.

Civil Engineering Research. GEORGE WIMPEY & CO. LTD., Hammersmith-grove, London, W.6. Materials testing and long-term research by a major civil-engineering contractor. Catalogue of facilities available at Wimpey's Central Laboratory: site investigations and foundation engineering; testing concrete and other road and building materials; mechanical and structural testing, including river models; also library and information services. Illustrated book describing work completed and in hand at the Laboratory.

"Magmaster." CRYSTON EQUIPMENT, LTD., Bridgwater, Somerset. A test unit for servicing scooters, motorised bicycles, motor cycles, motor mowers and other applications of small two-stroke and motor cycle engines. It consists of a central power drive by which magnetos can be driven in either direction under operating conditions and which includes variable spark gaps and other test features. Ignition and electrical test units can also be provided. Unillustrated leaflet.

Structural Steelwork. TEES SIDE BRIDGE AND ENGINEERING WORKS, LTD., Middlesbrough. Steelwork for towers, cranes, bridges, railway wagons, process plant and industrial buildings; drawing office and design facilities. Company now more than 100 years old, though under changing names. Illustrated booklet describing company's structural and general engineering equipment.

Joint Boxes for Polythene Cables. THE TELEGRAPH CONSTRUCTION AND MAINTENANCE CO. LTD., Theobalds-road, London, W.C.1. Boxes for jointing polythene-insulated and sheathed cables employed in telephone and control circuits. Technical details. Operating procedure. Dimensional data. Illustrated pamphlet, P.B.S./1.

RATIONAL DESIGN OF STAYED TUBE-PLATES

By J. P. Duncan, M.E., A.M.I.MECH.E., A.M.I.E.(AUST.)*

Concluded from page 463

This is the second and concluding part of an article which sets out to give a method that can be used for the design of circular tube-plates stayed to an adjacent rigid header or cover. The following discusses the condition of a circular plate, rigidly held at the periphery, but where the stays are eccentrically disposed. The references and appendices are given on page 528. The nomenclature, relevant to the whole of the article, was given on page 459.

ECCENTRIC LOADING OF CIRCULAR PLATES WITH ENCASTRÉ EDGES

Most tube-plates in medium and low-pressure heat exchangers have built-in edges. Due to the constant slope along the boundary in this case, a simple theoretical solution for the eccentrically loaded encastré plate is available. The ideas presented above can therefore be expressed precisely in simple general terms and verified by experiment. The complications occasioned by infinite series solutions and the need for approximations can be completely avoided.

The standard solution for the eccentrically loaded isotropic circular plate of rigidity D, having encastré edges as shown diagrammatically in Fig. 13, is believed to be due to Clebsch, 1862.[1] This solution for w consists of an infinite series similar to the Föppl solution for simple support. Clebsch remarked on the complexity of the result. Michell, 1901, derived a very simple solution of the problem by means of the transformation of inversion. A. E. H. Love has pointed out in his *Mathematical Theory of Elasticity*, article 154, that this is an exceptional case of the conformal transformation of the equation

$$\nabla^4 w = \frac{q}{D} = 0 .$$

The standard solution for deflection of a centrally loaded encastré plate is

$$w = \mathrm{K\,W}\left[\frac{a^2 - r^2}{2} - r^2 \log \frac{a}{r}\right] .$$ See Timoshenko,[5] equation 80.

By Michell's method, the above known solution inverts or transforms into the solution of an eccentrically loaded encastré plate. The solution is

$$w = \mathrm{K\,W}s^2\left[\tfrac{1}{2}\left(\frac{p^2 t^2}{a^2 s^2} - 1\right) - \log \frac{p\,t}{a\,s}\right] . \quad (28)$$

where W is now a concentrated load applied at A at radius p, and t is the distance of a point (r, θ) from A′, the inverse of the point A with respect to the circle of radius a. The relationship between a, p, s and t may be seen in Fig. 13. In Reference 4 a typical contour map of the deflected surface is given.

Combinations of Eccentric Loads.—The form of equation (28) is so simple that no approximations are necessary in arriving at "influence coefficients" and "influence ratios" for symmetrical stay combinations. As with the simply supported case, the symbols y_{pn} and y_0 will again be used to denote ratios of "influence coefficients" for deflection under the load and central deflection respectively.

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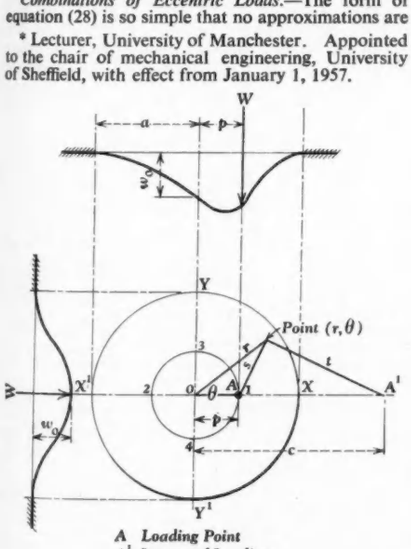


Fig. 13 Eccentrically loaded encastré circular plate. Illustrating Michell's inversion.

ANALYTICAL EXPRESSIONS FOR INFLUENCE RATIOS

Fig. 13 represents diagrammaticaly an eccentrically loaded encastré plate. Co-ordinates (s, t) appearing in equation (28) will first be transformed into co-ordinates (r, θ).

Let $\frac{p}{a} = x$.

Then equation (28) becomes

$$w = \mathrm{K\,W}s^2\left[\tfrac{1}{2}\left(x^2\frac{t^2}{s^2} - 1\right) - \log x\,\frac{t}{s}\right] . \quad (29)$$

From the geometry of Fig. 13,

$$t^2 = r^2 + c^2 - 2\,r\,c\cos\theta$$
$$s^2 = r^2 + p^2 - 2\,r\,p\cos\theta$$
$$a^2 = p\,c \quad \therefore \; c = \frac{a^2}{p} = \frac{a}{x}$$

Eliminating t and s in equation (29) by means of these relationships, a general expression for deflection due to a single load, W, is obtained as a function of r, θ and x. This expression is

$$w = \mathrm{K\,W}\left[\frac{(a^2 - r^2)\,(1 - x^2)}{2} - (r^2 + x^2a^2 - 2\,r\,a\,x\cos\theta) \times \log\sqrt{\frac{x^2r^2 + a^2 - 2\,r\,a\,x\cos\theta}{r^2 + x^2a^2 - 2\,r\,a\,x\cos\theta}}\right] . \quad (30)$$

By means of this equation, the deflection caused at a point (r, θ) by a load W at $(p, 0)$ can be found. For the combinations shown in Fig. 5(*c*) and Fig. 5(*f*), deflections at 1, 2, 3 and 4 in Fig. 13 are required. For a single load applied at point 1, Fig. 13, deflections are as follows.

At point 1, $\theta = 0$, $r = p = a\,x$

$$\therefore \quad w_1 = \mathrm{K\,W}\,a^2\,\frac{(1 - x^2)^2}{2} . \quad (31)$$

At point 2, $\theta = \pi$, $r = p = ax$

$$\therefore \quad w_2 = \mathrm{K\,W}\,a^2\left[\frac{(1 - x^2)^2}{2} - 4\,x^2\log\left(\frac{1 + x^2}{2\,x}\right)\right] . \quad (32)$$

At points 3 and 4, $\theta = \pm\frac{\pi}{2}$, $\cos\theta = 0$, $r = p = a\,x$

$$\therefore \quad w_3 = w_4 = \mathrm{K\,W}\,a^2\left[\frac{(1 - x^2)^2}{2} - 2\,x^2\log\sqrt{\frac{1 + x^4}{2\,x^2}}\right] . \quad (33)$$

Deflections under each of two loads, each $\frac{W}{2}$, acting simultaneously at points 1 and 2, Fig. 5(*c*), are

$$w_{p2} = \tfrac{1}{2}(w_1 + w_2) = \mathrm{K\,W}\,a^2\left[\frac{(1 - x^2)^2}{2} - 2x^2\log\left(\frac{1 + x^2}{2\,x}\right)\right] . \quad (34)$$

Deflections under each of four loads each $\frac{W}{4}$, acting simultaneously at points 1, 2, 3 and 4 in Fig. 5(*f*) are

$$w_{p4} = \tfrac{1}{4}(w_1 + w_2 + w_3 + w_4) = \mathrm{K\,W}\,a^2\left[\frac{(1 - x^2)^2}{2} - x^2\log\frac{(1 + x^2)\sqrt{1 + x^4}}{2\sqrt{2}\,x^2}\right] . \quad (35)$$

In all cases described by equations (31) to (35) the central deflection is the same and is

$$w_0 = \mathrm{K\,W}\,a^2\left[\frac{(1 - x^2)}{2} + x^2\log x\right] . \quad (36)$$

For any symmetrical combination of n stays at radius $p = a\,x$, the deflection along the circle of radius p will be a periodic function of θ.

Denoting this deflection by $w_{\theta n}$, for one stay $w_{\theta 1}$ is found from equation (30) as a function of x and θ by putting $r = a\,x$. Thus

$$w_{\theta 1} = \mathrm{K\,W}\,a^2\left[\frac{(1 - x^2)^2}{2} - 2\,x^2\,(1 - \cos\theta) \times \log\sqrt{\frac{(x^4 - 2\,x^2\cos\theta + 1)}{2\,x^2\,(1 - \cos\theta)}}\right] . \quad (37)$$

The deflection under a concentric load P = W is constant and equals

$$w_b = \mathrm{K\,W}\,a^2\left[\frac{(1 - x^4)}{2} + 2x^2\log x\right] . \quad (38)$$

(From Timoshenko,[5] equations 79 and 80.)

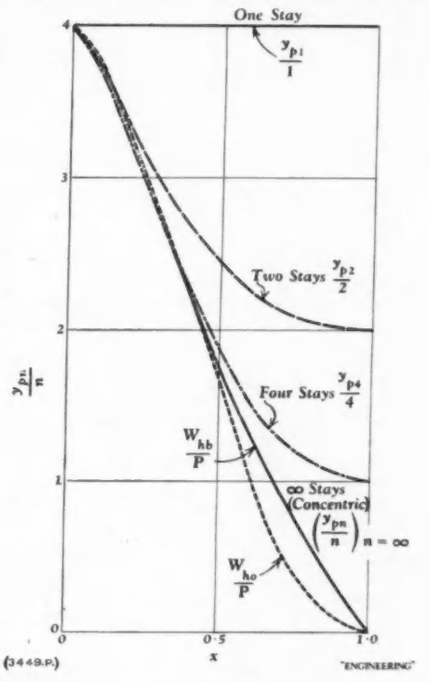
As n increases $w_{\theta n} \to w_b$. For a four-stay arrangement $w_{\theta 4}$ may be calculated from (37) by means of superposition. As for the simply supported case, the maximum and minimum values of $w_{\theta 4}$ will occur where $\theta = 0$ and $\theta = \frac{\pi}{4}$, respectively. The maximum value is w_{p4}, equation (35). The minimum value is

$$w_{\theta 4}\,(\mathrm{min}) = \mathrm{K\,W}\,a^2\left[\frac{(1 - x^2)^2}{2} - 0{\cdot}293\,x^2\log\sqrt{\frac{x^4 - 1{\cdot}414\,x^2 + 1}{0{\cdot}586\,x^2}} - 1{\cdot}707\,x^2\log\sqrt{\frac{x^4 + 1{\cdot}414\,x^2 + 1}{3{\cdot}414\,x^2}}\right] . \quad (39)$$

For $x = \frac{1}{2}$

$$w_{\theta 4}\,(\mathrm{min}) = \mathrm{K\,W}\,a^2\,[0{\cdot}115]$$
$$w_b = \mathrm{K\,W}\,a^2\,[0{\cdot}124]$$
$$w_{p4} = w_{\theta 4}\,(\mathrm{max}) = \mathrm{KW}a^2\,[0{\cdot}131]$$

Hence the substitution of concentric load P = W for even a four-stay system is not as good in this case as for the case of a simply supported edge. Fortunately exact "influence ratios" can be readily obtained



$$\frac{y_{p1}}{n} = 4$$

$$\frac{y_{p2}}{2} = 4\left[1 - \frac{4\,x^2}{(1 - x^2)^2}\log\left(\frac{1 + x^2}{2\,x}\right)\right]$$

$$\frac{y_{p4}}{4} = 4\left[1 - \frac{2\,x^2}{(1 - x^2)^2}\log\left(\frac{(1 + x^2)\sqrt{1 + x^4}}{2\sqrt{2}\,x^2}\right)\right]$$

$$\left(\frac{y_{pn}}{n}\right)_{(n\to\infty)} \to 4\left[\frac{1 + x^2}{1 - x^2} + \frac{4\,x^2\log x}{(1 - x^2)^2}\right]$$

Fig. 14 Influence ratios for encastré plates.

for points on the loading circle and, with little more trouble, for points on a second loading circle as in Fig. 5(*e*), 5(*g*), 5(*h*) and 5(*j*). Confining the argument to systems of stays on one loading circle, "influence ratios" are found as follows.

From equation (3) (with K written for K′)

$$k_h = \frac{K a^2}{8}(1 - x^2)^2. \quad . \quad . \quad (40)$$

Equations (31) (34) (35) and (38) may be written in general form

$$k_{sn} = \frac{n w_{pn}}{W} = f_n(x) \quad . \quad . \quad (41)$$

where $n = 1, 2, 3 \ldots . \infty$ (∞ corresponds to uniformly distributed load).

"Influence ratios" for integral values of n are given by

$$y_{pn} = \frac{k_{sn}}{k_h} \quad . \quad . \quad . \quad . \quad . \quad . \quad (41)$$

and are found for the encastré plate from

$$y_{p1} = 4 \quad . \quad . \quad . \quad . \quad . \quad . \quad (42)$$

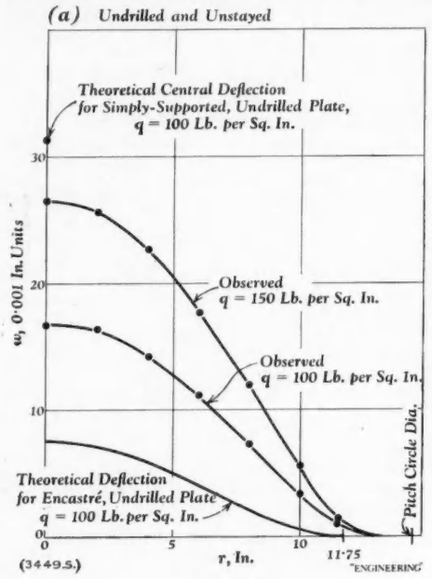
$$\frac{y_{p2}}{2} = 4\left[1 - \frac{4x^2}{(1-x^2)^2}\log_e\left(\frac{1+x^2}{2x}\right)\right] \quad (43)$$

$$\frac{y_{p4}}{4} = 4\left[1 - \frac{2x^2}{(1-x^2)^2}\log\left(\frac{(1+x^2)\sqrt{1+x^4}}{2\sqrt{2}.x^2}\right)\right] \quad . \quad . \quad . \quad (44)$$

$$\left(\frac{y_{pn}}{n}\right)_{(n\to\infty)} \to 4\left[\frac{1+x^2}{1-x^2} + \frac{4x^2\log x}{(1-x^2)^2}\right] \quad . \quad (45)$$

(Uniformly distributed concentric load)

Relationships (42) to (45) have been plotted in Fig. 14 over the range $x = 0$ to $x = 1{\cdot}0$. An example of the use of these factors is given later. The values


(a) Undrilled and Unstayed
Theoretical Central Deflection for Simply-Supported, Undrilled Plate, q = 100 Lb. per Sq. In.
Observed q = 150 Lb. per Sq. In.
Observed q = 100 Lb. per Sq. In.
Theoretical Deflection for Encastré, Undrilled Plate q = 100 Lb. per Sq. In.
Pitch Circle Dia.
w, 0·001 In. Units
r, In.
11·75
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"ENGINEERING"

Fig. 17(a)

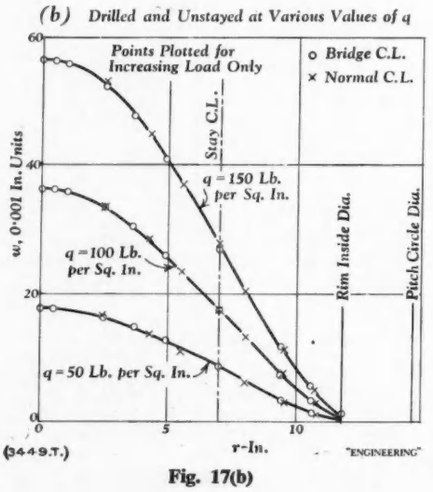
(b) Drilled and Unstayed at Various Values of q
Points Plotted for Increasing Load Only
o Bridge C.L.
× Normal C.L.
Stay C.L.
q = 150 Lb. per Sq. In.
q = 100 Lb. per Sq. In.
q = 50 Lb. per Sq. In.
Rim Inside Dia.
Pitch Circle Dia.
w, 0·001 In. Units
r-In.
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Fig. 17(b)

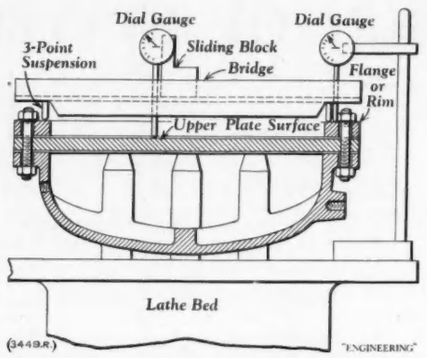

Fig. 15 Arrangements for measuring deflections.

$\frac{y_{pn}}{n}$ have been plotted rather than y_{pn} so that comparisons may be readily made with concentric loading for which $n = \infty$. The ratio $\frac{y_{pn}}{n}$ is equal to the ratio of total hydrostatic load, W_h, to total of stay loads, W, which produce the same deflection at the radius of loading. This ratio can therefore be evaluated for $n = \infty$ from the formula for concentric loading (Timoshenko equations, 79 and 80). Since k_{e1} is often small compared with k_h and k_{sn}, $\frac{y_{pn}}{n}$ gives at once an approximate idea of the total hydrostatic load which can be supported by a stay-system at a specific stay-stress. This is seen from equation (16) where, by putting $k_{e1} = 0$,

$$W_h = W\left(\frac{y_{pn}}{n}\right). \quad . \quad . \quad . \quad (46)$$

For the same case, individual stay loads due to hydrostatic load, W_h, can be readily found from

$$\frac{W}{n} = \frac{W_h}{y_{pn}}. \quad . \quad . \quad . \quad (47)$$

For accurate calculation of practical cases $k_{e1} > 0$ and equation (16) must be used.

EVALUATION OF STAY PATTERNS

Although stays are provided in order to limit the flexure-stresses in tube-plates, the stresses in the stays themselves often become the limiting factor in design. Assuming this to be so, the theoretical relationships in the two previous sections can be used to compare alternative stay arrangements.

With very high-pressure heat exchangers the space available for both flange bolts and internal stays is limited. In such instances it is of interest to see how a given total cross-sectional area of stays can

Figs. 17 Deflection traverses taken on tube-plate and header assembly under the four sets of conditions indicated.

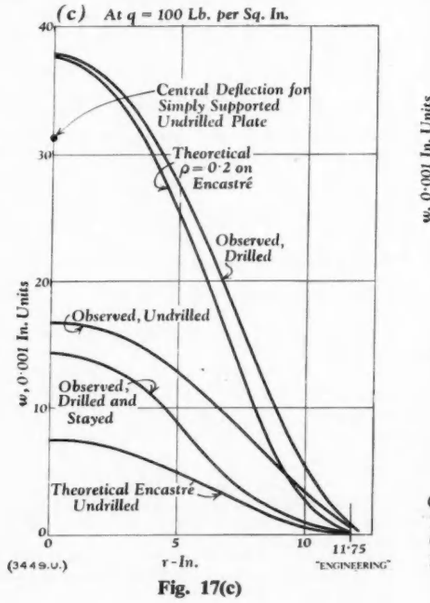

Fig. 17(c)

Fig. 16 Details of calibrated tube-plate stays.

be best disposed. In low-pressure units, the overall economy of manufacture hinges on the number of stays to be provided and the saving in tube-plate thickness and drilling time which they effect. Equation (16) provides an exact basis for these assessments. Let W_h, σ, E, l and a be the data in all that follows. Two cases require examination: (*a*) the saving in tube-plate thickness effected by n stays of constant total area $A_t = nA_n$, and (*b*) the total stay area required in n stays to limit the deflection in a tube-plate of fixed thickness to a fixed value at the stay locations. (In view of the reasoning given previously and from Fig. 10, this is roughly equivalent to fixing the hydrostatic load which the tube-plate carries in flexure.)

Consider symmetrical arrangements at one radius, $p = a\,x$.

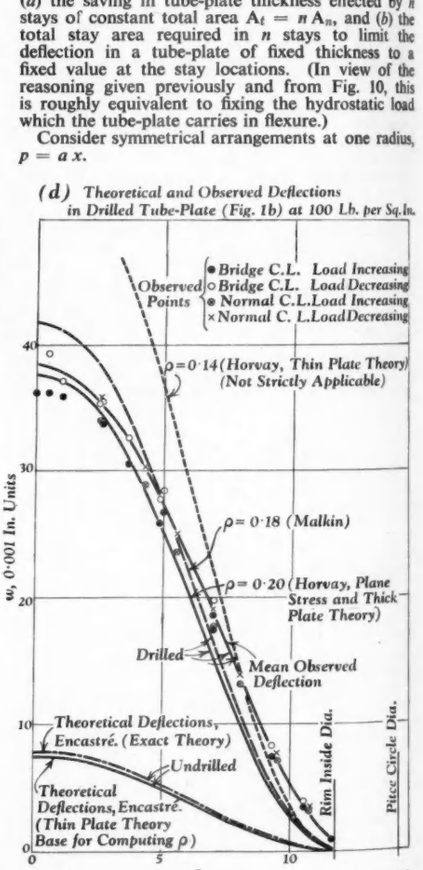
(d) Theoretical and Observed Deflections in Drilled Tube-Plate (Fig. 1b) at 100 Lb. per Sq. In.
Observed Points
● Bridge C.L. Load Increasing
○ Bridge C.L. Load Decreasing
● Normal C.L. Load Increasing
× Normal C. L. Load Decreasing
ρ = 0·14 (Horvay, Thin Plate Theory) (Not Strictly Applicable)
ρ = 0·18 (Malkin)
ρ = 0·20 (Horvay, Plane Stress and Thick Plate Theory)
Drilled
Mean Observed Deflection
Theoretical Deflections, Encastré. (Exact Theory)
Undrilled
Theoretical Deflections, Encastré. (Thin Plate Theory Base for Computing ρ)
Rim Inside Dia.
Pitce Circle Dia.
w, 0·001 In. Units
r-In.
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Fig. 17(d)

Note: The above curves are also given in Reference 2 (Fig. 36) where the loading should be given as 100 lb. per sq. in. (*not* 200 lb. per sq. in.).

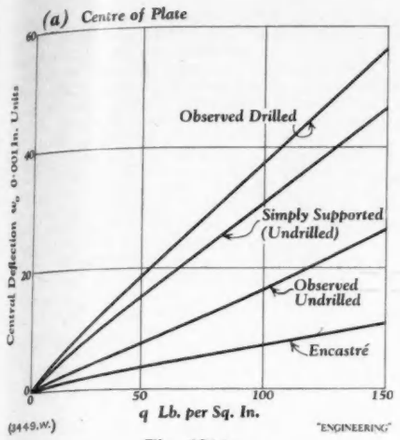

Fig. 18(a)

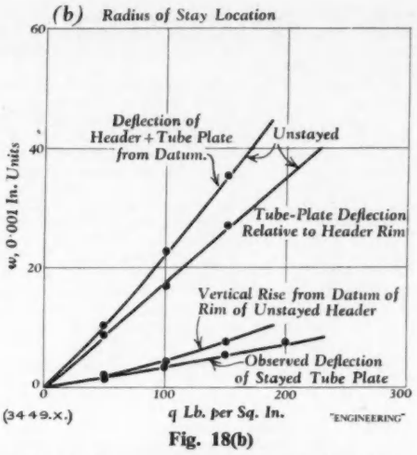
(b) Radius of Stay Location
w, 0·001 In. Units
Deflection of Header + Tube Plate from Datum.
Unstayed
Tube-Plate Deflection Relative to Header Rim
Vertical Rise from Datum of Rim of Unstayed Header
Observed Deflection of Stayed Tube Plate
q Lb. per Sq. In.
(3449.X.)
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Fig. 18(b)

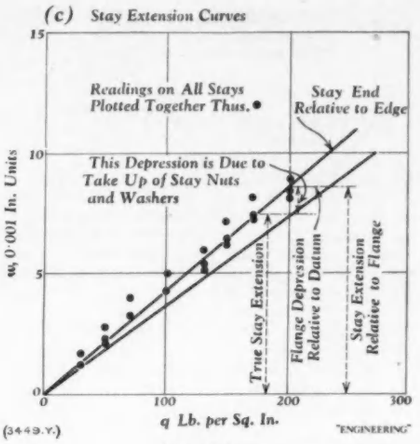
(c) Stay Extension Curves
Readings on All Stays Plotted Together Thus. •
Stay End Relative to Edge
This Depression is Due to Take Up of Stay Nuts and Washers
w, 0·001 In. Units
True Stay Extension
Flange Depression Relative to Datum
Stay Extension Relative to Flange
q Lb. per Sq. In.
(3449.Y.)
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Fig. 18(c)

Figs. 18 Pressure/deflection curves found when obtaining experimental confirmation of the author's theory.

Case (a):

$W = A_t \sigma$ = constant = $n A_n \sigma$,

W_h = constant,

$k_{e1} = \frac{l}{E A_n} = \frac{l n \sigma}{E W} = L n$, where L is a constant.

Therefore, from equation (16)

$$\frac{L}{k_h} = \frac{W_h}{W} - \frac{y_{pn}}{n}.$$

As W_h is constant k_h is inversely proportional to h^3 (undrilled plate) or $(h')^3$ (drilled plate).

$$\therefore \frac{L h^3}{N} = \frac{W_h}{W} - \frac{y_{pn}}{n} \quad \text{where N is constant.}$$

Hence

$$h^3 = C_1 - C_2 \frac{y_{pn}}{n} \qquad . \quad (48)$$

where C_1 and C_2 are constants for the problem. From this equation, h may be calculated for $n = 0$, 1, 2, 3, 4 etc., and for selected values of x. An example of calculation is given in Appendix II.

Case (b):

W_h = constant,

$W = n A_n \sigma$, (σ = constant, and n, A_n are variable)

$k_{e1} = \frac{l}{E A_n}$, $\left(\frac{l}{E}\right.$ = constant, and A_n variable$\left.\right)$

k_h = constant.

As stay extension has been fixed

$$\frac{W k_{e1}}{n} = \text{constant} = \frac{l \sigma}{E}.$$

Hence

$$\frac{W k_{e1}}{n k_h} = \frac{l \sigma}{E k_h} = \text{constant}.$$

Equation (16) may therefore be written as

$$W \frac{y_{pn}}{n} = W_h - \frac{W k_{e1}}{n k_h} = C_3$$

$$n A_n \sigma \frac{y_{pn}}{n} = C_3$$

$$\therefore A_n \sigma y_{pn} = C_3$$

$$A_n = \frac{C_4}{y_{pn}} \qquad . \quad . \quad . \quad (49)$$

where C_3 and C_4 are constants.

From (49) and Figs. 6 or 14, the relative areas of individual stays of n-stayed systems may be deduced. These are tabulated in Table I. The table shows the advantages of using the smallest number of stays possible consistent with the avoidance of localised tube-plate stresses. For instance, in the encastré case, two stays may be substituted for four by

TABLE I.—*Relative Areas of Individual Stays.*

Special Case: $x = \frac{1}{4}$, representing average conditions

n	Encastré		Simple support	
	A_n	d_n	A_n	d_n
1	1·85	1·36	2·77	1·67
2	1·53	1·24	1·85	1·36
3	—	—	1·31	1·15
4	1·00	1·00	1·00	1·00

Figures show comparison with a four-stay plate with specified edge condition.

increasing the stay diameter by only 24 per cent. or the area by only 53 per cent.

Stresses.—In this article it has been assumed that stay-stress is the limiting factor in design and the no mention has been made of the stresses in the tube-plate. In a previous paper[2], these latter were considered and it was shown that the drilling patterns of tube-plates introduce local stress concentrations. The area round a stay attachment is likely to exhibit similar features. A separate study of stresses in ligament systems is being made by the author. It may be possible to extend Föppl's[3] and Michell's[4] expressions for stress in eccentrically loaded plates to deal with certain simple stay arrangements providing the degree of isotropy of certain drilling patterns can be established. (See Reference 7.)

An account of some experiments with eccentrically loaded flat undrilled plates conducted before the availability of electric resistance strain gauges has been given by Professor R. J. Roark[6]. This article demonstrates the difficulty of stress calculation even when plates are undrilled.

APPLICATION TO AN ENCASTRÉ PLATE

Lest the simplicity of the design process itself is obscured by the complexity of the theory upon which it is based, the loads expected in the stays in Fig. 1(*b*) will be calculated and then compared with measured values in the actual assembly.

Data: Tube-Plate. In accordance with Fig. 1(*b*)

$a = 11{\cdot}75$ ins.

$h_1 = 1{\cdot}125$ in.

hole diameter $= \frac{23}{32}$ in.

hole pitch $= 1$ in.

$\frac{\text{ligament width}}{\text{pitch}} = \frac{9}{32} = 0{\cdot}281.$

$\rho = 0{\cdot}17$*

$p = 6{\cdot}938$ in.

$x = \frac{p}{a} = 0{\cdot}590$

$q = 200$ lb. per sq. in.

$\nu = 0{\cdot}3$

$E = 3 \times 10^7$ lb. per sq. in.

Edge assumed 100 per cent. encastré (justified later; see Fig. 19).

Stays. In accordance with Fig. 16.

$l = 8{\cdot}5$ in.

$d = 0{\cdot}800$ in.

$A = 0{\cdot}502$ in.

$E = 3 \times 10^7$ lb. per sq. in.

$\nu = 0{\cdot}3$

* This value is a mean of three values calculated according to theories proposed by Horvay and Malkin. This is an arbitrary procedure adopted by the author to resolve a difficulty which requiries further study. The value of ρ calculated by the methods of Horvay and Malkin can be read from Fig. 17(*d*) and, if used in lieu of $\rho = 0{\cdot}17$, result in calculated stay loads of 5·45 tons (Horvay—thin), 5·13 tons (Horvay—plane stress) and 5·22 tons (Malkin).

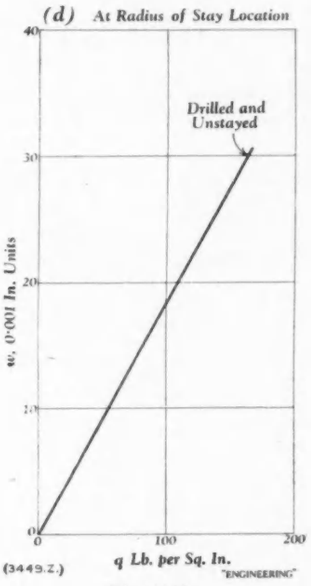

Fig. 18(d)

Header. For this calculation the header has been assumed to be infinitely rigid.

Calculations:

$$D = \frac{E h_1^3}{12(1 - \nu^2)} = \frac{3 \times 10^7 \times 1{\cdot}125^3}{12(1 - 0{\cdot}09)} = 3{\cdot}91 \times 10^6 \text{ lb.-in.}$$

$$D' = \rho D = 0{\cdot}17 \times 3{\cdot}91 \times 10^6 = 0{\cdot}665 \times 10^6 \text{ lb.-in.}$$

$$K' = \frac{1}{8 \pi D'} = 6{\cdot}01 \times 10^{-8}$$

From equation (3)

$$k_{h1} = \frac{K' a^2}{8}(1 - x^2)^2 = \frac{6{\cdot}01 \times 10^{-8} \times 11{\cdot}75^2 (1 - 0{\cdot}59^2)^2}{8} = 4{\cdot}39 \times 10^{-7}$$

From equation (4)

$$k_{e1} = \frac{1}{EA} = \frac{8{\cdot}5}{3 \times 10^7 \times 0{\cdot}501} = 5{\cdot}64 \times 10^{-7}$$

From Fig. 14. $\frac{p}{a} = 0{\cdot}59$

$$\therefore \frac{y_{p4}}{4} = 1{\cdot}51 \text{ or } y_{p4} = 6{\cdot}04.$$

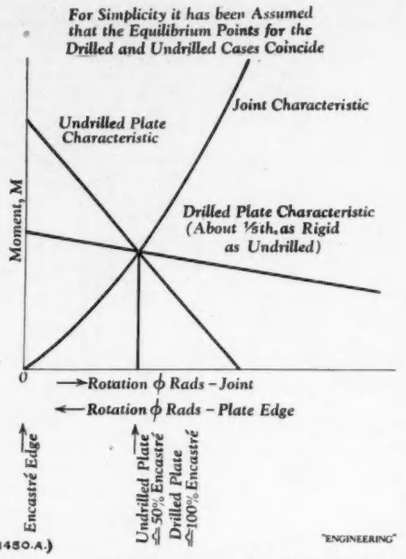
For Simplicity it has been Assumed that the Equilibrium Points for the Drilled and Undrilled Cases Coincide
Joint Characteristic
Undrilled Plate Characteristic
Drilled Plate Characteristic (About ⅛th as Rigid as Undrilled)
Moment, M
0
Rotation φ Rads – Joint
Rotation φ Rads – Plate Edge
Encastré Edge
Undrilled Plate ≙ 50% Encastré
Drilled Plate ≙ 100% Encastré
(3450.A.)
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Fig. 19 Graphical presentation of flange joint equilibrium.

Hence equation (12*a*), which is

$$W_{s1} = W_{s2} = W_{s3} = W_{s4} = W_h \left(\frac{k_{h1}}{y_{p4}\,k_{h1} + k_{e1}}\right)$$

can be solved by substituting the above values.

$$\therefore W_{s1} = \frac{\pi \times 23{\cdot}5^2 \times 200}{4 \times 2240}\left(\frac{4{\cdot}39}{6{\cdot}04 \times 4{\cdot}39 + 5{\cdot}64}\right)$$

$$= 5{\cdot}3 \text{ tons} \quad . \quad . \quad . \quad . \quad . \quad (39)$$

and W = 21·2 tons.

It may be noted from experimental results below (Fig. 20) that the four stay-loads measured on the physical assembly ranged between 4·8 and 6 tons with an average value of 5·2 tons.

EXPERIMENTAL CONFIRMATION

The tube-plate and header assembly shown in Fig. 1(*b*) were hydrostatically loaded during various stages of manufacture to test the validity of the above theory. The plate was first tested for deflection when undrilled and unstayed. It was next drilled to the pattern shown in Fig. 1(*b*) and again loaded hydrostatically, a Klingerite and shim-steel diaphragm being used to seal the tube-holes in a manner described by Duncan[2], 1955. Finally, stays as shown in Fig. 16 were fitted. These were specially designed to carry electric resistance strain gauges, protected by a floating steel cover-tube and were pre-calibrated in a standard tensile testing machine. It was thus possible to measure the loads in these stays when the tube-plate-header assembly was pressurised, again using a diaphragm to seal the tube-holes. Care was taken to avoid initial compression between the stay cover-bosses and the tube-plate so that the recorded load was entirely due to the applied hydrostatic pressure. Fig. 15 shows the experimental arrangements for measuring deflections and strains. It is only the deflections that are of interest here. Strains on the tube-plate surface and in the ligaments were also measured with miniature strain gauges but these results will be incorporated in a further general study of tube-plate stresses. Figs. 17(*a*) to 17(*d*) show deflection traverses across the plate-radius at various conditions of loading and drilling. It is important to notice that there is a significant rotation of the edge of the plate in the undrilled condition and little rotation in the drilled condition. This is shown by the finite deflection at the radius of 11·75 in. which is relatively of far higher order in the undrilled than in the drilled condition (Fig. 17(*c*)). It is further confirmed by the pressure-deflection curves of Fig. 18 (*a*). Here the undrilled plate is behaving as a semi-restrained supported plate. Its central deflection is about the mean of the theoretical deflections for an encastré and a simply-supported edge respectively.

On the other hand the drilled plate is behaving more like a truly encastré plate. Fig. 17(*c*) shows a very small deflection at radius 11·75 in. More significant than this is the deflection efficiency ρ of this plate with respect to the theoretical undrilled encastré plate. The value of ρ measured at the plate-centre on Fig. 18(*a*) is $\frac{10{\cdot}5}{56{\cdot}3} = 0{\cdot}19$. This agrees roughly with the predictions of Horvay and Malkin for continuously drilled plate to which this tube-plate bears close resemblance. (See Duncan,[2] 1955, Fig. 5.) It may be seen from Fig. 17(*c*) that $\rho = 0{\cdot}17$ fits the observed curve even better in the region round $r = 6{\cdot}938$ in.

The contention that the edge conditions of the undrilled and drilled plates differ is easily justified by the following graphical representation for which the author is indebted to Mr. G. Sved. In Fig. 19, let the moment versus rotation characteristic of the Klingerite jointing material be as shown. Superimpose on this graph the edge-moment versus rotation characteristics of the undrilled and drilled plate. Under conditions of equilibrium, the joint-restraining moment must equal the plate edge-moment. It can be seen from Fig. 19 that the restraining moment for the drilled plate must be much nearer the encastré moment than that for the undrilled plate. The drilled plate may therefore be considered as having 0·17 to 0·19 times the theoretical rigidity of an undrilled plate of the same thickness with encastré edges. It would be unsound to use ρ', the ratio of experimental values for the drilled and undrilled condition[2], as a check against the theoretical value ρ used above.

The measured stay-loads on stays 3 and 4 were 4·8 tons (on the tube-plate bridge) and 5·1 tons (at the tube nest) respectively. On stays 1 and 2 the measured loads were 5·1 tons and 6·0 tons respectively, a different system of strain gauges being used on these two stays. The anisotropy of the plate about its axes of symmetry as demonstrated in Fig. 12 accounts for the "nest" stays carrying a greater load than the "bridge" stays. The average of these measured stay loads, 5·2 tons, agrees very well with the purely theoretical figures of 5·3 tons calculated.

CONCLUSIONS

A theoretical method has been presented by means of which the loads induced in individual stays of symmetrically stayed tube-plates can be calculated. For a simple system of n similar stays at one radius the load in each, W_{s1}, is given by

$$W_{s1} = \frac{W}{n} = W_h \left(\frac{k_h}{y_{pn}\,k_h + k_{e1}}\right)$$

where k_h and k_{e1} are "influence coefficients" calculated from formulae for the deflection of a circular plate under hydrostatic load, W_h, and for the extension of the stay per unit load respectively, and y_{pn} is "influence ratio" which has been derived theoretically and plotted in convenient form for design purposes.

Methods for solving more complex systems of stays have been outlined and all the necessary formulae needed have been supplied.

Where room for stays is limited or there exists a need to make comparative economic studies of alternative arrangements of stays and tube-plates, the formulae derived provide a theoretical basis of comparison and how the relative advantages of reducing the number of stays employed to a minimum.

The ideas presented are to be supplemented by data in a previous paper by the author and by the consideration of stresses in tube-plates to be embodied in further articles.

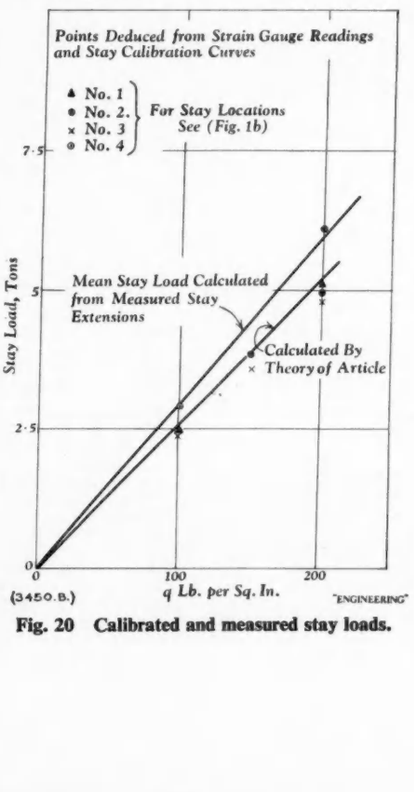

Fig. 20 Calibrated and measured stay loads.

Acknowledgments.—Experimental work carried out in connection with this study was made possible through the co-operation of the Metropolitan-Vickers Electrical Company, Limited, Manchester, Thompsons (Castlemaine) Limited, Castlemaine, Victoria, and the University of Adelaide. Particular thanks are due to Dr. W. H. Darlington and Dr. J. M. Dodds of Metropolitan-Vickers, Mr. J. G. Burnell, Technical Director of Thompsons (Castlemaine) Limited, and Professor H. H. Davis of the University of Adelaide. The author also expresses his appreciation of the personal assistance and criticism offered by officers of all the above bodies. Mr. W. H. Harvey's assistance at Castlemaine and the valuable suggestions and criticisms of Mr. G. Sved are also gratefully acknowledged.

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APPENDIX I—DEFLECTION OF CONCENTRICALLY LOADED PLATES

The following equations, taken from Reference 5, are given below in the notation of this article.

Timoshenko, equation 77—Deflection outside a concentric load:

$$w = \mathrm{K\,P}a^2\left[\left(1 - \left(\frac{r}{a}\right)^2\right)\left(1 + \frac{m-1}{2(m+1)}(1-x^2)\right) + \left(x^2 + \left(\frac{r}{a}\right)^2\right)\log\frac{r}{a}\right].$$

Timoshenko, equation 78—Deflection within a concentric load:

$$w = \mathrm{K\,P}a^2\left[(1-x^2)\left(\frac{3m+1}{2(m+1)} - \frac{m-1}{2(m+1)}\left(\frac{r}{a}\right)^2\right) + \left(x^2 + \left(\frac{r}{a}\right)^2\right)\log x\right].$$

APPENDIX II—VALUE OF STAYS IN TERMS OF PLATE THICKNESS

The following calculations consider the effect of modifying the number of stays in Fig. 1(*b*) by reference to equation (48). Numerical values are taken from *Data* (under "Application to an Encastré Plate" page 527) and the subsequent calculations.

Equation (48) is $h^3 = C_1 - C_2\frac{y_{pn}}{n}$

Constants must first be evaluated in specific cases. Consider the arrangements in Fig. 1(*b*).

$k_{e1} = 5{\cdot}64 \times 10^{-7} \qquad n = 4$

$k_{e1} = \mathrm{L}\,n \quad \therefore \mathrm{L} = 1{\cdot}41 \times 10^{-7}$

$k_h = 4{\cdot}39 \times 10^{-7} \qquad h^3 = 1{\cdot}125^3$

$$\therefore k_h = 6{\cdot}26 \times \frac{10^{-7}}{h^3} = \frac{\mathrm{N}}{h^3} \quad \therefore \mathrm{N} = 6{\cdot}26 \times 10^{-7}$$

$$\frac{\mathrm{N}}{\mathrm{L}} = \frac{6{\cdot}26}{1{\cdot}41} = 4{\cdot}44 \qquad q = 200$$

$$W_h = \frac{\pi \times 23{\cdot}5^2 \times 200}{4 \times 2240} = 38{\cdot}7 \text{ tons}$$

$\mathrm{W} = 21{\cdot}2$ tons

$$\frac{W_h}{W} = 1{\cdot}825$$

$$C_1 = \left(\frac{W_h}{W}\right)\left(\frac{N}{L}\right) = 1{\cdot}825 \times 4{\cdot}44 = 8{\cdot}11$$

$$C_1 = \frac{N}{L} = 4{\cdot}44$$

As a check on equation (48),

L.H.S. $= 1{\cdot}125^3 = 1{\cdot}42$

R.H.S. $= 8{\cdot}11 - 4{\cdot}44 \times 1{\cdot}51$

$= 8{\cdot}11 - 6{\cdot}70$

$= 1{\cdot}41$

If two stays are used each having twice the cross-sectional area of those in the four-stay system, the plate thickness required is found from

$$h^3 = 8{\cdot}11 - \frac{y_{p2}}{2}(4{\cdot}44)$$

$$= 8{\cdot}11 - 2{\cdot}25 \times 4{\cdot}44 = -1{\cdot}89$$

$$\therefore\ h = -1{\cdot}24.$$

This apparently absurd result simply means that the fixed hydrostatic load W_h could never fully stress these stays to the design limit, σ. When applied to very thick stayed tube-plates (feed heaters) in which the plate carries in flexure a large proportion of the total load, the above treatment would result in a reduced positive value of h.

If, in view of the above negative result, two stays identical to those shown in Fig. 16 are used (the total stay area now being $2A_4$ instead of $4A_4$ as above) the small increase in plate thickness required to offset the omission of two stays can be calculated as follows:

Equation (16) may be written

$$\frac{k_{c1}}{n k_h} = \frac{W_h}{W} - \frac{y_{pn}}{n}$$

$W_h = 38{\cdot}7$ tons

$W = 10{\cdot}6$ tons $\quad \therefore \frac{W_h}{W} = 3{\cdot}65$

$k_{c1} = 5{\cdot}64 \times 10^{-7}$

$n = 2$

$\frac{y_{pn}}{n} = 2{\cdot}25$

$$\therefore k_h = \frac{\frac{k_{c1}}{n}}{\frac{W_h}{W} - \frac{y_{pn}}{n}}$$

$$= \frac{2{\cdot}82 \times 10^{-7}}{3{\cdot}65 - 2{\cdot}25} = 2{\cdot}01 \times 10^{-7}$$

This "influence coefficient" can be obtained by increasing plate thickness from

$$1{\cdot}125 \text{ in. to } 1{\cdot}25 \times \left(\frac{4{\cdot}39}{2{\cdot}01}\right)^{\frac{1}{3}} = 1{\cdot}46 \text{ in.}$$

Hence the addition of approximately $\frac{1}{4}$ in. in plate thickness enables two stays, with their sheathing bosses, to be dispensed with.

The resulting two-stay system is also sufficiently simple to permit stress calculations on the plate by the Michell method. Local stress concentrations at boundaries of drilled areas and near stay attachments are more difficult to assess.

With no stays, the plate then carries the whole load of 38·7 tons in flexure and the plate thickness should be $h = (8{\cdot}11)^{\frac{1}{3}} = 2{\cdot}01$ in. Hence two stays save 0·56 in. of plate thickness, four stays save 0·876 in. of plate thickness.

In the sense that stays save plate thickness, the first two stays used are therefore $\frac{0{\cdot}56}{0{\cdot}876 - 0{\cdot}56} = 1{\cdot}77$ times as effective as the second two stays added to make up a four stay system.

★ ★ ★

CHROMIUM-PLATED PLASTICS

The advent of I.M.-Plastichrome mouldings, in which plastic mouldings are chromium-plated by an electrodeposition process, constitutes an interesting development in plastics technology. The firm responsible, Industrial Mouldings (Warwick) Ltd., Emscote-road, Warwick, claims that components so treated can be used in almost any application where zinc-alloy die castings are employed, and in some instances where a die casting or stamping would be impracticable.

No technical details regarding the process are available for publication but it is stated that laboratory tests indicate that the resistance to corrosion and blistering is of a high order. The mouldings are lighter than die castings or stampings of similar size and it appears that their strength compares favourably with that of pressure die castings. One definite advantage possessed by the mouldings is that their thermal conductivity is negligible—a matter of importance when they are used in domestic heating or refrigerating appliances. In this connection it is interesting to note that, after a number of tests, Flavel, Sidney and Company, Limited, Eagle Foundry, Leamington Spa, Warwickshire, have incorporated two I.M.-Plastichrome mouldings in their new "Envoy" gas cooker, where metal components would have been impracticable owing to the transmission of heat.

RECORDING STRAINS IN ROTATING MECHANISMS

SIX-CHANNEL EQUIPMENT FOR HELICOPTER ROTOR

A survey of "Strain Gauge and Blade Motion Recording Systems for Helicopters" was the subject of a lecture given recently in London before the Helicopter Association of Great Britain by Mr. P. D. MacMahon, of Saunders-Roe Limited. In the earlier part of the paper, Mr. MacMahon reviewed existing techniques using recording mirror galvanometers, and the possibilities of confluent pulse techniques, telemetering and tape-recording, none of which, in the present state of development, are ideal for the small helicopter. In the main part of his paper, an abridged version of which is given below, Mr. MacMahon described a six-channel equipment for recording both strain-gauge signals and blade motions developed by Saunders-Roe Limited for use on the Skeeter helicopter.

In strain gauging helicopter rotor assemblies, the problem of recording steady stresses—which normally change only with change of flight conditions—simultaneously with dynamic stress is particularly difficult, because the fatigue-inducing vibratory stresses are not generally very large compared with the steady stresses. Consequently, for any given recording field a choice must be made between accurate recording either of relatively low-amplitude high-frequency detail or of large-amplitude static detail. For this reason direct-current energising of the strain gauges is preferred since it is then simple to reject steady components.

Signal amplitudes rarely exceed a few millivolts, and signal frequency bandwidth is approximately 2 to 300 cycles per second. The signal may be extremely complex in form.

Photographic-recording mirror galvanometers are usually employed for recording the strain gauge signals, and electronic amplification of the signals is necessary.

Great importance is attached to any method of avoiding the use of slip-rings in low-level signal circuits, since slip-rings form one of the most prolific sources of troubles in practical tests. Thus it is desirable either to amplify the signals before taking them out through slip-rings to a recording system in the cockpit, or to eliminate slip-rings by installing the recorder or camera in the rotor hub. The advantages of this latter system cannot be fully realised until a suitable camera is developed.

RECORDING STRAINS AND BLADE MOTIONS

In 1953, Saunders-Roe Limited put forward proposals to the Ministry of Supply for a light-weight six-channel strain-gauge recording equipment specifically for helicopters, which catered not only for all the stress measurements required but also for measuring the blade motions.

To avoid the practical difficulties associated with the use of slip-rings at low signal levels, it was proposed that pre-amplifiers should be mounted on the rotor head. The relatively high signal output would then be passed through slip-rings to a panoramic display unit below in the cockpit (Fig. 1), which was to provide a visual assessment of the oscillatory stress characteristics, with complete control of signal level by individual attenuating facilities for each of the six channels. The signals would be recorded in a small multi-galvanometer camera.

The steady-state stresses were to be measured directly by reference to a wide-sweep galvanometer mounted in the display unit, the signals feeding this galvanometer being proportional to the unbalance present in the pre-amplifiers, which, in turn, would be directly related to the strain-gauge bridge or transducer connected to it. Attenuating facilities would also be incorporated with this.

Power supplies were to be derived from a three-phase 400 cycle rotary inverter running

Fig. 1 The panoramic display unit in the helicopter cockpit. Individual attenuation is provided for each of the six channels on which the oscillatory stress characteristics are displayed. Steady-state stresses are indicated on a wide-sweep galvanometer.

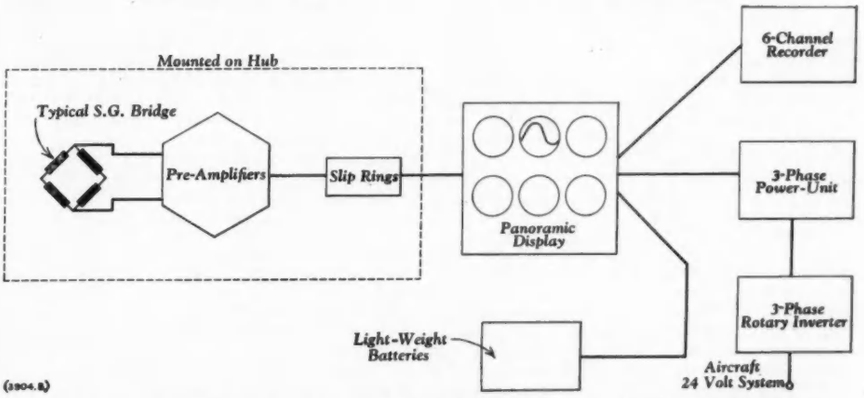


Fig. 2 The layout of the Saunders-Roe helicopter strain-gauge recording equipment.

off the aircraft 24 volt system, each phase of 115 volts alternating current being stepped up or down by transformers to provide regulated, unregulated and extremely high-tension voltage. This power supply system promised to reduce weight and bulk to a minimum.

It was proposed to provide excitation for the strain-gauge bridges or other transducers and the pre-amplifier heaters with a lightweight Venner accumulator, to be housed in the pre-amplifier structure itself, mounted on the hub, to reduce the number of slip-rings required. Finally, the whole equipment was to be sufficiently " rugged " to withstand all types and levels of vibration, and reasonably foolproof.

The pre-amplifier formed the most exacting part of the design. The effects of vibration, changes of temperature and the behaviour of the valves when under centrifugal loads all presented problems which were overcome by the careful choice of components, re-design and sustained tests on a spinning rig. The final choice of valve for the pre-amplifier was a " ruggedised " VX.7117, similar to types in current use in guided weapons. It will withstand sustained use in unusual circumstances for longer than a normal production valve.

Drift from direct-current amplifiers is an almost inevitable problem, and a figure of 1 millivolt per half hour was aimed at and eventually achieved. This is equivalent to 1,000 lb. per sq. in. stress (Duralumin) when using Saunders-Roe foil strain gauges excited with 12 volts direct current.

Based on the findings of the first series of full-scale tests on the rotor test tower, modifications were made to reduce the absolute drift/stress error to 1 millivolt per half hour. At the same time the overall sensitivity was doubled.

The final proving of the equipment on a Mach 5 Skeeter aircraft necessitated the provision of a special set of slip-rings made to watchmaker's tolerances. To facilitate mounting the equipment in the aircraft, it was " broken down " into several self-contained units, with multi-way cables connecting the respective circuits. Fig. 3 shows the pre-amplifier installed on the Skeeter helicopter.

With the drift problem finally overcome, the tests went ahead without incident until their completion on December 16, 1955. In all, 46 test flights were made, of which 35 provided full and acceptable stress recordings. Fig. 4 is a typical record of the oscillatory loads.

PRE-AMPLIFIER

The pre-amplifier valves used are of the " wired-in " type, eliminating variation of the valve pin contact potential. They are type VX.7115, a " ruggedised " version of the Brimar 13D3 with flying leads in order to achieve maximum robustness. The increased heater consumption of this type as compared with other types of double triode results in a higher cathode temperature and, consequently, less tendency to variations of emission with heater voltage. The resistors used are not critical in value, but should be reasonably matched to ensure the compensating action of the circuit.

The connections to the pre-amplifier assembly are made through an 18-way Plessey Mark 4 plug and socket. This carries the 12 output signals, the high-tension positive and negative, the 24 volts from the Venner accumulators and the 24 volts to operate the relays. An additional 18-way plug and socket are provided for connecting up to a field calibrating unit. The pre-amplifier outputs and supplies are fed through a set of 20-way slip-rings mounted on the main rotor shaft. The use of silver rings and silver graphite brushes is recommended.

When blade motions are being measured, the strain gauges are replaced by high-accuracy potentiometers. With these it is unnecessary to use a pre-amplifier and, hence, the equipment has been designed so that the pre-amplifiers can be individually removed and connections from the potentiometers made directly to the turret. In this case, the energising voltage for the potentiometers is obtained from the high-tension supply to the pre-amplifiers by way of suitable dropping resistors in either side. This ensures that the mean potential of each potentiometer output is approximately the same as the pre-amplifier anode potential.

Fig. 3 The pre-amplifier installed on the hub of a Skeeter helicopter.

BRIDGE-BALANCING AND METERING PANEL

In the original scheme it had been proposed to incorporate a cathode follower in each pre-amplifier and switch a micro-ammeter across each output to measure the unbalance. With the re-designed circuit this is no longer possible and, hence, a single cathode follower valve with the meter connected permanently between the cathodes has been incorporated in the bridge-balancing panel. The switching is performed on the grids of this valve by connecting them into any one of the inputs from the pre-amplifiers. In order to obtain maximum stability the heaters of this valve are supplied from the Venner accumulators.

As it is not possible to have bridge-balancing controls in the input circuits to the pre-amplifiers, these are incorporated in the bridge-metering circuit and enable an artificial zero to be obtained on the meter, thereby correcting for any unbalance in the strain gauge or pre-amplifier circuits. A second bank of contacts working in conjunction with the channel selector permits an appropriate potentiometer to be connected across the bottom of the cathode load resistors of the cathode follower. The slider of this control is earthed and, hence, a variation in the current taken by each half of the cathode follower will result. These balance controls would be set with the rotor stationary after a suitable warming-up period.

The balance meter is of the edgewise pattern and has a 3½ in. scale and a 125-0-125 microamp. movement. A shorting switch normally closed is connected actoss the meter. The reading is such that full scale either side corresponds to 5 millivolts input to the pre-amplifiers, but this is checked by means of the calibrating unit in test work. The sensitivity of the meter is not affected by the position of the balancing potentiometer.

In order to amplify further and record the dynamic stress variations it is necessary to isolate the amplifiers from the metering circuits which are directly coupled to the pre-amplifiers. For this purpose a bank of capacitors has been incorporated in the inter-connecting circuitry.

AMPLIFIER AND MONITOR UNITS

The amplifiers and monitors are built in sub-assemblies which plug into the main frame of the cabinet and are completely interchangeable with one another. The facility of individual monitoring for all six channels has been incorporated in the equipment to facilitate rapid operation of the equipment when setting the respective gain levels. The amplifiers, each of which has a balanced attenuator across the input giving 33 db total attenuation in 3 db steps, consist of a single balanced stage, feeding in parallel a cathode follower and a further stage of amplification, the latter supplying the signal at a level suitable for scanning the monitor tubes. Negative feedback is taken from the output feeding the monitors to the cathodes of the input stage, across which is placed a preset gain control. The overall gain is set to about 750 and it is arranged so that full scan on the monitor tubes corresponds to a trace width of about 8 mm. peak-to-peak on the film. The coils of the galvanometer elements in the recorder, nominally 1,500 ohms apiece, constitute the cathode loads of the cathode follower output stage. In this manner, the amplifier is balanced throughout and maximum rejection of hum pick-up and high-tension voltage fluctuation is ensured.

The amplifiers have been designed to have a frequency response flat from 3 cycles up to

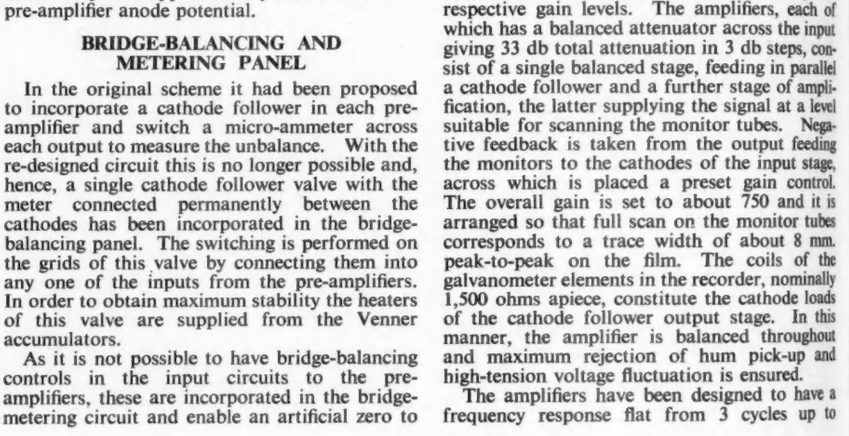


Fig. 4 Typical oscillatory load record taken during flight trials on the Skeeter helicopter.

1 kilocycle per second. The phase shift at 3 cycles is not greater than 5 deg. as read on the film or 15 deg. on the monitor tube. The monitor tubes have long-persistence screens to enable good presentation of the lower frequency phenomena to be obtained. Each tube is equipped with individual X and Y shift, brightness and focus controls being situated at the rear of the chassis so that they are only accessible when the chassis is removed for functional checking or maintenance. The tubes are operated with the positive earthed and the cathodes supplied from a 1,000 volt negative line. The time base consists of single pentode connected as a direct coupled transitron. It is a complete sub-assembly.

The recording camera is of French manufacture. The galvanometers, which are of the moving-iron type, are connected in the cathodes of the output stage of the amplifier. These galvanometers are mounted in the camera on two bars and arranged to reflect a beam of light directly on to a slit behind which runs the film—in this case, 60 mm. recording paper. In addition, three relays are mounted in the camera carrying small mirrors on their pallets which enable them to transmit timing pulses on the film. One of these is normally actuated by a built-in timing device working off the drive motor, leaving the other two free for marking azimuth position, the latter being derived from a device in the slip-ring housing.

BLADE MOTION MEASUREMENT

The measurement of blade motion is best performed with a high-acuracy potentiometer coupled to the moving surface in such a way as to follow the angular motion. In order to obtain the required resolution, it is necessary to choose a potentiometer having a large number of turns, which inherently entails a winding of fairly high resistance. Since the angular movement of a helicopter blade is of the order of 30 deg. to 45 deg. as a maximum, it is advantageous to use some means of gearing up the movement of the potentiometer wiper to obtain full use of the available winding angle.

In the system evolved it has been decided to use potentiometers with a 360 deg. winding, having a centre tap, and employing two wiper arms diametrically opposite. The energisation voltage is applied across the winding and the centre tap, and the output is derived between the wipers. In order to minimise the effects of backlash, a step-up ratio of no more than 1·66 to 1 is employed between the blade and the potentiometer spindle; thus 1 deg. movement of the blade produces 100 minutes rotation of the spindle. The limit of resolution is the movement of the wiper between one turn of the winding and its neighbour. Hence to give the necessary resolution, the potentiometer must be wound with six turns per degree, or 2,160 turns for the full 360 deg. of winding, as a minimum.

As mentioned previously, the potentiometers are supplied from the stabilised high-tension supply via suitable resistors to ensure the correct sensitivity and mean operating potential. When operating with the six-channel equipment the sensitivity in terms of electrical output will have to be about 140 mV for 2·5 deg. of blade movement, which corresponds to the full-scale deflection of the bridge balance meter on its most sensitive range. This means a potential of 7 volts must be applied across each potentiometer.

An important feature of this equipment is the ease with which results may be interpreted. The equipment in its developed form appears to be superior to any other system in use at the present time for accurately assessing oscillatory and steady stresses in rotary wing aircraft. Its relatively small bulk and weight (76 lb. in all) have enabled full-scale testing to be carried out successfully in the world's smallest fully-articulated helicopter, without reducing the scope of measurements or reliability.

Strain-gauge/blade-motion calibrations are made directly, thus dispensing with the hazards of calculation errors and expediting analysis of oscillatory and steady stress.

NO MORE SMOKE

SOME PROBLEMS AND PROVISIONS OF THE CLEAN AIR ACT

The twenty-third annual conference of the National Smoke Abatement Society, whose headquarters are at Palace Chambers, Bridge-street, London, S.W.1, was held this year at Southport, Lancashire, from October 3 to October 5. Brief extracts from some of the papers that were presented are given here.

Following the welcome by the Mayor of Southport and the Presidential Address by Sir Ernest Smith, Mr. Enoch Powell, Parliamentary Secretary, Ministry of Housing and Local Government, spoke of the Clean Air Act, and the measures being taken to enforce it. Before the end of this year a day would be fixed for the commencement of the provisions relating to smoke in central areas: new furnaces, chimney heights, and such other provisions as were required in connection with these sections. Regulations for prescribing authorised fuels were in preparation; others would follow regarding the use of smoke-density meters and the measurement of dust and grit emission.

The body of the Act would come into operation in the spring of 1958, but he urged that the bulk of the work which it would necessitate should be carried out well before then. He also drew attention to the so-called seven year " period of grace " and pointed out the very limited defence that could be evoked. If alterations or improvements required under section 1 were deferred when they might have been carried out, the defence of section 2 would be of no avail. He hoped that harmony and collaboration would continue between the local authorities and the Alkali Inspectorate. Under section 23, the Minister would shortly be appointing the Clean Air Council, which would be a consultative body for the purposes of reviewing progress and obtaining special advice. Much research work was still required, perhaps particularly in the field of exhaust pollution from motor transport.

HEALTH AND POLLUTION

The first of the two papers on the medical aspects of air pollution was on the " Clinical Significance of Dirty Air " and was given by Dr. P. J. Lawther, director of the Medical Research Council Group for research on atmospheric pollution, working at St. Bartholomew's Hospital, London. After referring to King Edward I's Order on smoke abatement of 1288, he went on to emphasise the difficulty of obtaining true samples. It might well be that the apparent increase in the lethal nature of smogs was in fact due to the large number of people with chronic heart and lung disease who were now kept alive by modern medicine, but who were unable to withstand the unusual conditions created by smog. Speaking of motor vehicles, Dr. Lawther said that the Diesel engine need not emit black smoke if properly adjusted, and the law forbidding black smoke ought to be rigorously enforced. He also spoke of the possible dangers of carbon monoxide concentration in city streets, and the large amount of pollution emitted by the private car when taken in relation to the number of passengers carried.

Dr. Handley B. Howell, Consultant Radiologist of the Weston-super-Mare Hospital Group, spoke of " The Health Aspects of Air Pollution from Road Vehicles." He said that it had been his lot to carry out radiological investigations on many thousands of chests annually for the last twenty years. In the course of this the obvious increase in chest diseases from irritant causes, and particularly the alarming increase in lung cancer, had given him much food for thought, expecially since the middle years of the last war. The rapid increase in the use of the internal combustion engine, and especially those of the heavy oil or Diesel type, struck one as a very possible answer. Until recent years all problems of atmospheric pollution had concentrated around the congested industrial areas, being almost wholly concerned with the products of coal combustion. Naturally this led to a concentration on the sulphurous elements and coal soot or ash.

Of the cancer producing contents of vehicle exhausts, he said that the Diesel engine working under optimum conditions was found to produce none of the cancer creating agent 3:4 benzpyrene at any speed or loading. However, the moment the fuel/air ratio was altered to a richer than normal ratio, 3:4 benzpyrene was produced in greater quantities than in the case of the petrol engine. In conclusion, Dr. Howell said that it was noteworthy that, of all cancer in man, the biggest increase is shown in cancer of the lung, gullet and upper air passages. This at once suggested that the causative agent was most likely inhaled.

SMOKELESS FUEL DEVELOPMENTS

Mr. W. Hodkinson, of the North Western Gas Board, introducing a paper by his chairman, Mr. D. P. Welman, said that if we really wanted to come to grips with the problem of the 19 million tons of smoky coal burnt in household grates in the " black " areas we needed the help of all the smokeless fuels. And, in particular, since we were trying to displace a solid fuel used for long-period heating, we should preferably find a smokeless solid fuel. The Beaver Committee had come to the conclusion that gas coke must provide the main solution.

The gas industry had a very important part to play in the provision of smoke-free air that could not be met by electricity and oil. There was no technical obstacle in the equipment of the industry to prevent its meeting the demand; and there was no lack of suitable coal with which to do it. The price of coke was fully competitive with coal and the cost of the necessary appliance was small in relation to the benefits which the consumer and society in general would derive from coke burning. The quality of coke was being steadily improved and new fuels were being developed to meet the special need of the ordinary open grate.

Mr. Hodkinson described two new fuels of high standards that were now being produced by his Board—" Thermax " and " Thermalite." While Thermax, a fuel likely to prove most suitable for closed stoves, was not yet on the market, it was hoped that Thermalite would satisfy in every respect the demand for a clean, easily ignited, easy burning fuel giving a cheerful open fire. He said that his Board felt that Thermalite can and will offer one of the greatest advances yet made in the campaign for clean air, and would satisfy in the fullest measure the objectives of the Beaver Committee.

Dr. W. Idris Jones, director general of Research, National Coal Board, speaking of the Beaver Report's policy on solid fuels, said that it would give the National Coal Board two main tasks to carry out. The first of these was to arrange that the large quantities of bituminous coal displaced from the smokeless areas were made available for conversion into electricity and gas, coke, or other type of manufactured smokeless fuel. The second was to increase its own production of manufactured smokeless fuels, and this would call for a vigorous development programme to translate into commercial production the results of the research work at the board's research establishments and other establishments.

Dr. Jones described two of the main ways in which the National Coal Board was endeavouring to increase the range of coals which could be used to make smokeless fuels. In one of these processes, which are still under development, hot air or hot gas was bubbled through a bed of

finely-powdered coal until the coal particles were suspended in the stream, giving the appearance of a boiling fluid. The resulting oxidized coal could then be made into the board's normal "Phurnacite" fuel. The other process, called fluidised carbonisation, is very similar to that used on a large scale in the oil industry; there are, however, problems in its use for coal which are not met with for oil.

There could hardly be a person in this country, said Professor A. B. Semple, medical officer of Health for Liverpool, who was not aware of the effects of air pollution. But did the householder put modern fuel appliances before his requirements for television and other wonders of this electronic age? When managements were considering expenditure, did the boiler house come first or last? Did public bodies prefer the promotion of private empires to the fostering of public good by the replacement of obsolete steam-raising plant?

He doubted whether the manufactured fuels could meet all the domestic demand, and increased needs would have to be met by the use of gas coke. Unfortunately, there was considerable resistance to the use of coke. There were traditional objections and mistaken notions that coke gave rise to fumes.

Speaking of certain special industrial processes which the Beaver Committee had recommended should remain with the central Alkali Inspectorate, Professor Semple thought that many large local authorities would make a request for these to be transferred to their jurisdiction, as provided for in the Act. Local officers were more aware of the discomfort and psychological effects to the inhabitants adjacent to many of these highly technical processes, and were inculcated with a sense of urgency to secure the abatement of smoke nuisances.

LOCAL AUTHORITIES

Speaking of the problems for local authorities that the Act would raise, Alderman G. H. Goulden of Salford, referring to industrial smoke abatement said that the system of exemption by annual certification during the seven-year period of grace available under the Act, would permit some sort of programming by local authorities, manufacturers, the Ministry of Fuel and Power and the National Coal Board. It demanded alert watchfulness by local authorities lest they found themselves the victims of unscrupulous concerns deliberately contriving to defer plant modernisation to the last year of the seven.

In speaking of the abatement of domestic smoke, Alderman Goulden said that smoke control area development was obviously geared to solid smokeless fuel availability and, as this largely meant coke, the gas industry must look to its laurels for it was not just more coke that was needed, but better coke at a price which would commend the fuel to everyone. He said that apparently there was no incentive to produce coke at a price less than that of middle quality coal, but could not a free-burning super-coke be marketed under a trade name? In return for the superior product, domestic consumers would, he felt sure, be prepared to pay a reasonable price for it.

Mr. H. V. Cass, Chief Public Health Inspector of Oldham, said that the implementation of the Clean Air Act would fall largely on the shoulders of the Health Inspectors. These additional responsibilities would be undertaken by them according to the enthusiasm and encouragement given to them by their respective local authorities. The new Act, while not being all that the smoke abatement enthusiast might have desired, could be considered to be a realistic attempt to implement the recommendations of the Beaver Committee.

The defences of lighting up from cold, and the unavoidable failure of plant and apparatus, appeared to be reasonable, said Mr. Cass. The defence of unsatisfactory fuel was, however, one which some considered might nullify the objects of the Act. It would be necessary for steps to be taken to rebut in evidence all three defences.

Mr. Cass ended by saying: "The successful enforcement of the Clean Air Act, like the majority of public health and similar legislation that health inspectors are called upon to administer, will depend upon health inspectors and local authorities endeavouring to secure the good will, education and co-operation of all the interests concerned, rather than by wielding the big stick of prosecution."

THE NEXT CHAPTER

The seventh Des Voeux memorial lecture was given by Sir Hugh Beaver, K.B.E., M.I.C.E., M.I.Chem.E., under the title of "Clean Air—the Next Chapter." Sir Hugh said there were three points he wished to consider: What is the most that can be got out of the Act; what has to be done to ensure that the most is indeed got out of the Act; and what other action remains for us and/or the Government to do to complete the campaign.

Regarding furnace smoke, the responsibility rested squarely on the shoulders of the local authorities. Here there were four problems—staff to carry out the work; the definition of dark smoke; infringement by night; and the "unsuitable fuel" clause. Collective thinking and action between local authorities would be needed to deal with these. The question of ensuring that works were employing the "best practical means" of preventing the emission of smoke or grit inevitably involved both adequate staff and direction. While applauding the fairness of such remarks as "It is nevertheless not definitely established that the boilers are the main source of dust emission, there being other potential offenders in the locality" which sometimes appeared in the Chief Alkali Inspector's report, yet a start must be made somewhere.

The prevention of domestic smoke, Sir Hugh continued, involved first the detailed survey of the area, secondly (before the local authority could reasonably make an order), the assurance that both fuels and appliances would be available in sufficient quantities and finally the conversion of about a million buildings (perhaps twice that number of installations) a year if it were the intention to secure the effective application of the Clean Air Act in 10 to 15 years. The Ministries of Housing and Local Government, and of Fuel and Power had both given assurances during debate that fuels and applicances would be forthcoming, but they would not appear by pronouncement only: a co-ordinated programme of production and distribution must be worked out.

Sir Hugh said that his committee had been struck by the lack of co-ordination among investigators and by the gaps in knowledge, both clinical and chemical. There was also the problem of pollution by vehicle exhausts for which the Act made no coverage. He urged that the Clean Air Council recommended by his committee should be set up as quickly as possible, but warned that in the end, success would depend on public pressure.

FACTORY ELECTRICITY SUPPLY

Converting a System

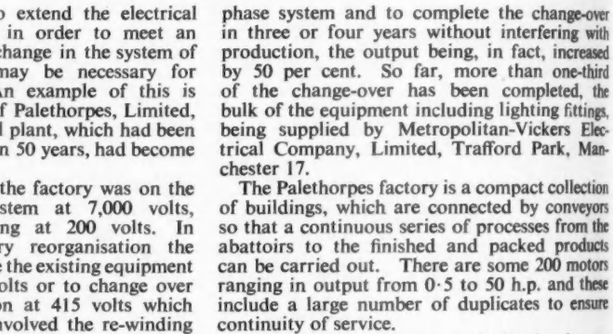
Where it is necessary to extend the electrical equipment of a factory in order to meet an increasing load, a basic change in the system of supply and operation may be necessary for reasons of efficiency. An example of this is provided at the factory of Palethorpes, Limited, at Tipton, where electrical plant, which had been in operation for more than 50 years, had become seriously overloaded.

The original supply to the factory was on the two-phase three-wire system at 7,000 volts, internal distribution being at 200 volts. In considering the necessary reorganisation the alternatives were to double the existing equipment and to continue at 200 volts or to change over to three-phase distribution at 415 volts which would, of course, have involved the re-winding or replacement of the existing motors. An argument against the extension of the two-phase system was that the new transformers and switchgear would be more costly than the corresponding three-phase equipment, and that the motors and control gear, being non-standard, would be adversely affected in frame sizes, cost and delivery.

It was therefore decided to adopt the three-phase system and to complete the change-over in three or four years without interfering with production, the output being, in fact, increased by 50 per cent. So far, more than one-third of the change-over has been completed, the bulk of the equipment including lighting fittings, being supplied by Metropolitan-Vickers Electrical Company, Limited, Trafford Park, Manchester 17.

The Palethorpes factory is a compact collection of buildings, which are connected by conveyors so that a continuous series of processes from the abattoirs to the finished and packed products can be carried out. There are some 200 motors ranging in output from 0·5 to 50 h.p. and these include a large number of duplicates to ensure continuity of service.

In the extended factory, distribution is over four main circuits from a new substation, where the incoming two-phase three-wire supply is brought in at 7 kV from the system of the Midland Electricity Board. Control is effected from a two-panel board through which 500 kVA Scott-connected transformers are fed. The secondary sides of these transformers, from which a 415 volt three-phase supply is given on the



In the new substation which forms part of the extension at the works of Palethorpes, Ltd., Tipton, a two-phase incoming supply at 7 kV is converted to a three-phase supply at 415 for internal distribution.

four-wire system to the factory, are connected to an air-break medium voltage switchboard. The general arrangement of the substation is shown in the illustration; the high voltage switchboard is on the right, the Scott-connected transformers in the background and the medium voltage switchboard on the left. The four main distribution circuits are controlled separately by fuse-switches.

In carrying out these extensions considerable importance is being attached to power factor correction. Two of the distribution circuits have therefore been fitted with capacitors of British Insulated Callender's Cables manufacture, which are controlled by a relay. The remaining circuits are to be similarly equipped.

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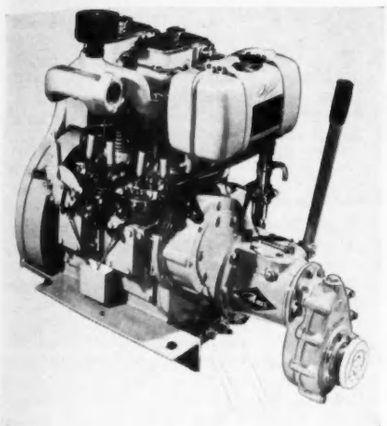

SMALL MARINE ENGINES

Air and Water Cooled Models Up to 12 H.P.

Four new Diesel engines for marine use have been added to the range now being manufactured by Petters Limited, Causeway Works, Staines, Middlesex. They consist of single and twin cylinder models, which can be either air or water cooled. Air cooling, particularly on a marine engine, eliminates the troubles of a corrosive cooling water supply, or the heavy double system using a heat exchanger. Frozen waterjackets are impossible, and easy starting has been maintained. The twin-cylinder air-cooled engine, with reverse and reduction gearboxes, is shown in the illustration.

The bore and stroke of the engines are 80 mm. and 110 mm., respectively, and the single-cylinder air-cooled version develops 5 h.p. at 1,500 r.p.m. and 6 h.p. at 1,800 r.p.m. (12 hour rating). The water-cooled model has the same rating. Cooling air is provided by a fan which is combined with the flywheel, and is distributed across the cylinders by sheet metal ducting. It has been found that the engine can be enclosed in a casing and can draw its air from below the floor boards (returning it to the same place) without overheating. This arrangement reduces noise and can perform the service of bilge ventilation.

One of the main considerations behind the design of these engines has been to restrict the overall dimensions as much as possible while retaining accessibility. A typical example is the use of a flexible dipstick that can be drawn out vertically, although the guide tube for it is set at an angle in the sump. One result of this policy has been to produce an engine which can conveniently be cased in all round and used in smaller boats without taking up an excessive amount of space. The twin-cylinder models, as a type, have been officially approved for use in lifeboats, and single-cylinder engines will be accepted on individual inspection. They have undergone severe tests, including operation under tropical conditions.

Marketing

SIZING UP THE MARKET

Market research is a subject to which we shall return from time to time, since comprehensive and accurate knowledge of the market is obviously one of the keys—if not the key—to successful selling. By way of introduction, it may be useful to define its main functions.

Planning Output.—Demand must be forecast. To some extent this can be done by analysing the company's sales records. But whether previous years' sales can serve as a reliable guide to the future depends on the strength and nature of competition (i.e., how much the company are gaining from or losing to competitors), on the impact of new products which may impinge on the markets for the old, on the economic weather, on the measures that governments may take to protect their countries' economy. Most of these factors can be assessed if trouble is taken to study the facts available and to get information from the market. As a large and highly successful manufacturer remarked recently, "I and my colleagues in the board-room have our opinions and hunches, but what we shall make, and how much of it, is determined by the findings of our market research people. And it works."

Organising the Sales Force.—The sales manager must know where demand lies if he is to apply his resources effectively. To know his industry's sales by areas, and to know who is buying his competitors' products and why they are preferred is essential if he is to set realistic objectives for representatives or agents, to route his men effectively, to brief them and in general to assist them in carrying out their task.

The Promotion of Sales.—A good knowledge of the competitive position in each sales area and export market will enable the Board to determine how much should be spent and where. Market research can assess, within broad limits, the return which can be expected on projected expenditure. The knowledge obtained of the customers' reactions will assist in selecting the type of advertising, special sales campaign or other measures likely to secure the desired result.

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Art of Advertising

Modern Publicity is the title of an annual review of international advertising art published by the journal *Art and Industry*. It aims at showing what is best in the advertising of 30 countries and is obviously an important reference for those who must keep informed of world ideas and standards in this field. This year's volume is a stimulating display of talent, although its effect is almost spoilt by poor and unimaginative layout. The pages are overcrowded by reproductions of posters crammed together, competing for effect, and are tiring to the eye. It is difficult to compare the work of different countries as everything is thrown together without much evidence of a plan. The exception is the packaging section, which is well designed and effective.

There is much in this year's volume that is of direct concern to engineering and metal manufacturers. Impressive for their originality and vigour are the advertisements of capital goods industries, which are addressed to the trained minds of expert buyers. In this field there are marked national differences. Germany and Switzerland tend to rely on a bold practical approach, whereas Britain makes much more use of human interest and the humorous approach, as is seen in the advertising of Accles and Pollock, British Die Casting, the 600 Group and the Metal Window Association. There is also a tendency on the part of some British companies—in particular those selling iron and steel, chemicals and aircraft—to make, in the words of the editor, "an appeal to reason, as distinct from sentiment, instinct or even sentimentality." Imperial Chemical Industries, Shell Petroleum, United Steel and Hawker-Siddeley are good examples.

The section of the editor's preface devoted to a discussion of the design and layout of company accounts is worth careful study. American and Canadian companies are alive to the publicity value of well-produced accounts, but with some notable exceptions (Shell, Dunlop, British Aluminium and a few others) British companies miss their opportunity "to transform a formidable statement of facts and figures into something which would not only be satisfying to the shareholder but help his understanding and arouse the interest of labour." As a source of ideas and a yardstick for comparison, *Modern Publicity* is invaluable.

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Selling to Eastern Europe

The recent meeting in Geneva of the trade and payments experts from the Soviet Union, western and eastern Europe was an important one for British engineering. Although exports from the United Kingdom were considerably higher during the first half of this year than in the first half of 1955, they fell below the rapidly rising figures reached in the second half of last year. Exports of Land Rovers and heavy lorries to Poland, and west German exports of ships to the Soviet Union, are the two main items on the western trade list. Orders have been secured for commercial vehicles by the Standard Motor Company but so far the amount of business placed with British engineering firms has been disappointing. Little progress has in fact been made since the meeting last April between Sir Anthony Eden and Mr. Bulganin, when both stated theirdesire to extend trade between their two countries. But the Soviet intention to spend during the coming five years, "if there are no trade restrictions or discriminations," between £800 and £1,000 million on purchases in the United Kingdom still stands.

The technique of selling engineering products to eastern Europe is becoming fairly well known. It means steady pounding at the doors of Government trading organisations in the capitals of the countries concerned. There would appear to be no short-cut and progress is slow. The Russo-British Chamber of Commerce, the British Council for the Promotion of International Trade, the Federation of British Industries and a number of merchanting houses are in a position to give useful advice and information. Apart from the ban on the export of strategic goods, however, the most serious obstacle is that the Soviet Union and eastern European countries want heavy industrial equipment and ships, all of which are in urgent demand throughout the world. The opportunities of expanding trade will be watched carefully by the engineering industry.

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This new feature in ENGINEERING *will deal with topics likely to be of interest to the sales engineer and to others who are concerned with marketing. The subject matter will range widely—from information and comment on marketing techniques, sales promotion methods and sales forecasting to discussions of the analysis of sales records, the trends of demand in particular industries and market developments. With the co-operation of the firms concerned, actual case studies will be quoted and comments invited from readers. The coverage will be world-wide, and will include topical information from the United States, Germany and other countries whose engineering industries compete with ours.*

We aim to make this column a lively commentary on what is happening in the world of engineering sales and a source of useful information for those whose job it is to sell engineering products.

CALDER HALL SERVICES RENDERED

Continued from page 505

In the continuation of our article on the contributions made by contractors and sub-contractors to the building and installation of the Calder Hall nuclear power station, we cover the following sections of the plant: the gas circulating system, the turbine house, pumps and valves, the reactor control-rod mechanism, and the arrangements for charging and discharging fuel elements. In a concluding section of the article we intend to refer to the graphite moderator, reactor monitoring and control equipment, electrical apparatus, tubing, pipes and ducts (where these have not already been covered in other sections), materials (including steel plate and lubricants), and various ancillary items. A list of contractors and sub-contractors with addresses will appear at the end of the article, in a subsequent issue. Though we have endeavoured to mention all the firms known to have been engaged in this work, we cannot be responsible for omitting companies that were not included in the list compiled by the United Kingdom Atomic Energy Authority. In addition, we have only been able to describe equipment if information has been made available and been cleared by the Authority for publication. Previous articles on Calder Hall have included an introductory description of the plant (October 5, page 420) and an account of the engineering problems involved (October 12, page 475).

Gas Circulation

C. A. Parsons and Company, Limited, have contributed a number of major items to the Calder Hall station, for they have been responsible not only for the turbine plant, which will be described in a later section, but also for the gas circulating system. We have already dealt with the engineering problems involved in designing and building these items, but give here in addition a summary of their main details.

To remove the heat from each reactor, there are four motor-driven Parsons carbon dioxide gas circulators. The electric current for each motor is supplied by a motor-driven generator, and the entire system operates on the Ward-Leonard principle. The main blower motors and also the motor generator sets were made by *Mather and Platt, Limited*. The mass flow of carbon dioxide through the reactor in normal operation is 1,964 lb. per second, and the reactor inlet conditions, that is, those at circulator outlet, are 100 lb. per sq. in. and 284 deg. F. (140 deg. C.). The circulator is of centrifugal pattern and to keep gas leakage down to the minimum consistent with reliable operation, an overhung design was adopted. This simplifies the shaft sealing problem. The speed of the four circulators on each reactor can be remotely controlled by a single operation in the main control room, and, in addition, arrangements are made to ensure that all circulators operate at the same speed. A view of one of the two 1,500 horse-power blowers used to circulate the coolant for No. 1 reactor is shown in Fig. 13. The direct-current motor of the Ward Leonard set, the blower volute and the method adopted for suspending the expansion joint can be seen.

The large gas ducts between the reactor, heat exchangers and circulators were also provided by Parsons. The most important feature of these are the methods adopted to maintain a leak-tight system while ensuring sufficient flexibility. This is necessary so that, despite the very considerable expansion differentials involved, the loads and moments on the reactor vessel, heat exchangers and circulators to which they are connected, are kept to very low limits. To achieve this, bellows of the tied type were adopted: those for uniplaner deflections being of the single hanger type; but where flexibility is required in more than one plane, the bellows are of gimbal pattern. To support the weight of the large ducts, valves and bellows, constant-support hangers have been fitted. Some of the larger types employed were manufactured in this country for the first time. Constant-support hangers made by *Vokes Genspring, Limited* were used in the Calder Hall station, including their W.3 and W.4 units. Fig. 14 shows Vokes Genspring hangars supporting a bellows assembly; they can take a load of 30,000 lb. over a travel of 3⅜ in., or 8,400 lb. over 12 in. In general, each length of duct, valve and bellows unit is separately supported.

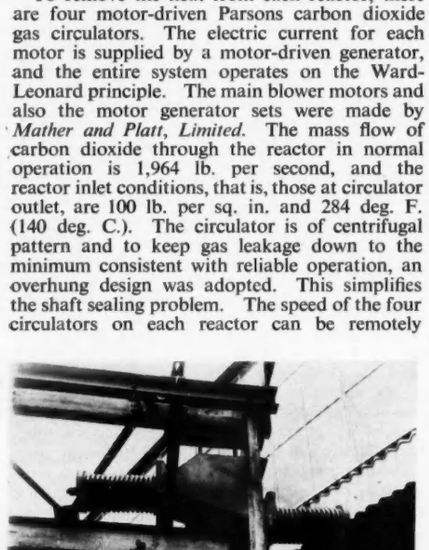


Fig. 14 Vokes Genspring constant-support hangars were used to carry ducting at the Calder Hall station. Those shown here supporting a bellows assembly in the reactor coolant circuit can take a load of 30,000 lb. over a 3⅜ in. travel, or 8,400 lb. over a total distance of 12 in.

Fig. 13 One of two 1,500 horse-power blowers which circulate carbon dioxide coolant through No. 1 reactor at Calder Hall. The motor of the Ward Leonard set for controlling blower speed, the blower volute, and the method of suspending the expansion joint are shown.

Turbine Plant

A description of the turbo-generating plant, which was also built by *C. A. Parsons and Company, Limited*, has already appeared in an earlier article, but the main details may be repeated here. The turbine room contains four Parsons turbo-generators each having a normal rating of 21 MW. A view of the turbine hall has already been published, but one of the turbo-generator sets is shown in Fig. 15. The plant, however, is provided with a design margin sufficient to enable it with certain blading modifications to give an output of 23 MW per machine. Two turbo-generators with surface condensing plant, two main line de-aerators and one dump condenser with its associated de-superheaters, form the major units which work in conjunction with each reactor. The basement of the Calder Hall "A" turbine hall is illustrated in Fig. 16, which shows, on the right, feed-water de-aerators, made by *Hick, Hargreaves, Limited*, steam receivers, a de-superheater (*Hopkinsons Limited*) and the feed cooler for the heat exchangers serving No. 1 reactor.

Steam is supplied from the heat exchangers at two conditions: high pressure steam at 185 lb. per sq. in. and 590 deg. F. (310 deg. C.), and low pressure steam at 38 lb. per sq. in. and 340 deg. F. (170 deg. C.), the steam after expansion in the turbine being condensed in the surface condenser at a vacuum of 28·25 in. (mercury barometer 30 in.). The turbine runs at a speed of 3,000 r.p.m. and comprises a single flow high-pressure

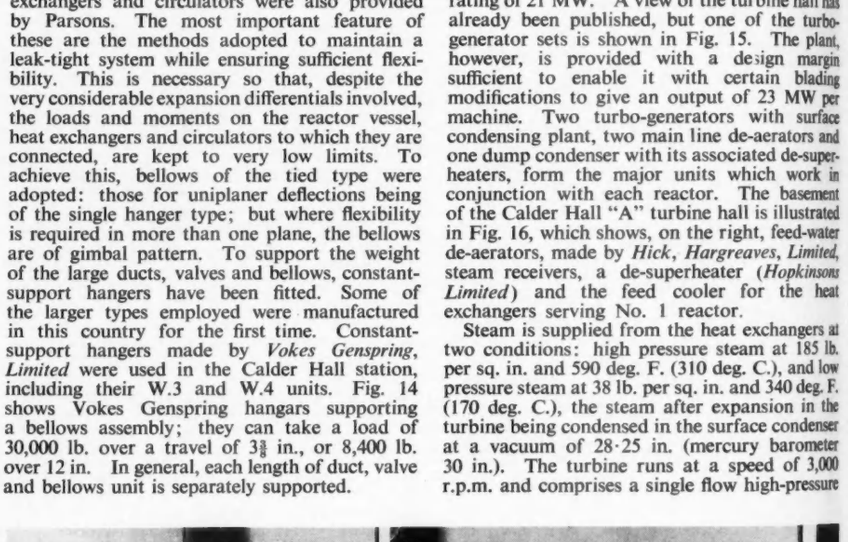


Fig. 15 Parsons turbo-generator set for the Calder Hall power station. There are two sets per reactor making four in all, each with a normal rating of 21 MW, but capable with certain blading modifications of developing 23 MW. Steam is supplied from heat exchangers on the duel-pressure cycle.

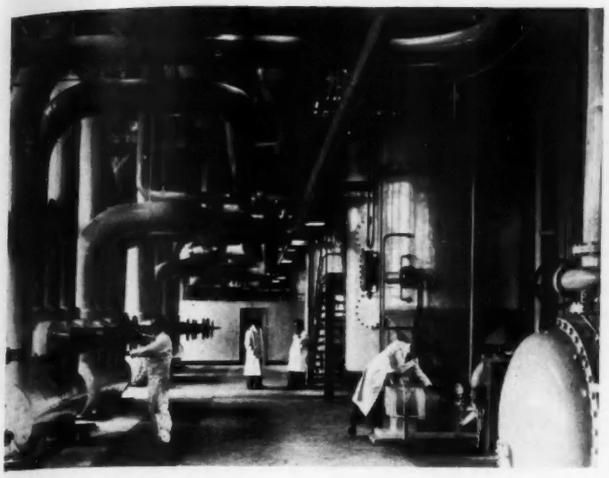


Fig. 16 Basement of the Calder Hall "A" turbine hall showing, on the right, the Hick Hargreaves feed-water de-aerators, and also steam receivers, a de-superheater and the feed cooler for No. 1 reactor's heat exchangers.

Fig. 18 Parsons high and low-pressure dump valves. The operating shaft to the Hopkinson spray control cubicle for the primary de-superheater can be seen to the rear of the valves.

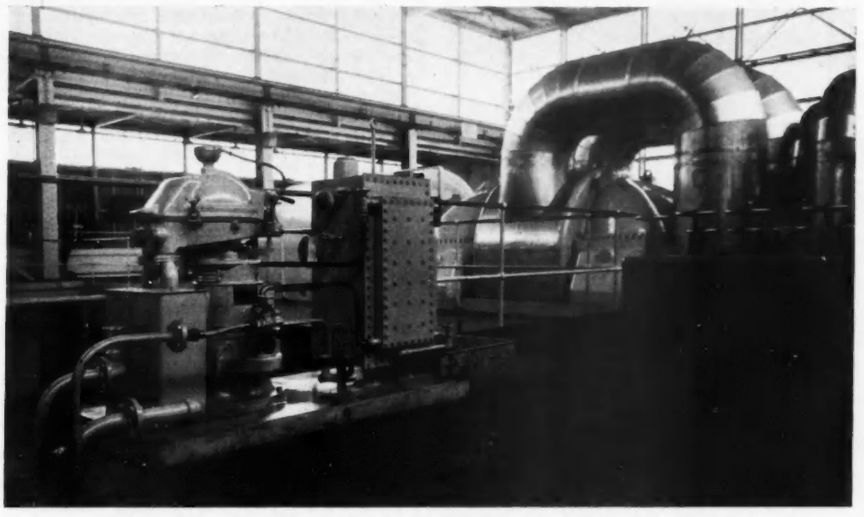


Fig. 17 Hopkinson centrifugal purifier for the continuous treatment of the turbine oil.

unit solidly coupled to a double-flow low-pressure unit. The blading throughout the turbine is of all reaction type. Two steam chests, high pressure and low pressure, are arranged on opposite sides of each turbine, and contain an emergency stop valve and governor valve.

As the full heat output from the reactor must be consumed at all times, the turbines normally operate under steam pressure control, so that the temperature of the gas circulating between the heat exchangers and reactor can be governed independently. In the event of the reactor heat output exceeding that which can be absorbed by the turbines the surplus steam is automatically passed to a dump condenser. The high-pressure and low-pressure governor valves, emergency stop valves and the steam pressure regulator are operated hydraulically by oil supplied from a gear-type pump. This is mounted on a cross shaft driven by worm-gearing from the steam end of the high-pressure turbine shaft. A lubricating oil pump supplying oil to the oil coolers and bearings is mounted on the same cross shaft. A centrifugal purifier, made by *Hopkinsons Limited*, which provides continuous purification of the turbine oil, is shown in Fig. 17. The main condenser is generally in accordance with modern power-station practice and has a cooling surface of 32,500 sq. ft. using 1 in. diameter tubes which are expanded into the tube plate at one end and sealed off with metallic packing and ferrules at the other.

To use any steam in excess of normal load requirements and to cover for the possibility of the station being suddenly disconnected from the grid when on load, steam dump condensers are provided, each being capable of taking the whole of the steam diverted from two fully loaded turbo-generators. Primary de-superheaters using mechanically and thermostatically controlled spray nozzles reduce the temperature of the steam entering the condenser to about 300 deg. F. (150 deg. C.). Secondary de-superheaters are fitted in the top chamber of the condenser to reduce the temperature of the steam still further to saturation point. The high-pressure and low-pressure dump valves are illustrated in Fig. 18. In the rear is the spray-control cubicle for the primary de-superheater; the operating shaft linking the dump valve to the spray control equipment can be seen at the side of the cabinet. The cubicles, which with other de-superheating equipment were also supplied by Hopkinsons contain both mechanically and electrically operated spray control valves.

The generators are of standard design, each with a continuous maximum rating of 23,000 kW and operating with a voltage of 11,500 at 0·8 power factor. The generators work on a closed air ventilation system, the cooling air being provided by two motor-driven fan units working in parallel when the machine is fully loaded.

Valves

Valves are necessarily associated with both the coolant gas circuit and the steam system. Of most interest in the gas circuit are the 54 in. diameter power-operated wedge gate valves, made by *J. Blakeborough and Sons Limited*. These serve to isolate parts of the system, as when a blower or heat exchanger is to be inspected; one of them is shown in Fig. 19. They are mounted on the hot and cold carbon dioxide ducts between the pressure vessels and their associated heat exchangers, and are 16 in number. Another 16 will be used in the Calder Hall "B" station. Half the valves in each case are designed for vertical mounting, and half for horizontal mounting in vertical ducts. They are of outside screw construction, with cast-steel casing and gate, monel-metal seat and face rings, and aluminium-bronze stem and tubular rising spindle. The operating gear is electric-motor driven and capable of opening or closing the valve in 2¼ minutes. Remote control and remote open-shut indication are provided. The design and manufacture of these valves presented certain special problems arising from the operating conditions involved. The working temperature, for example, was to be 700 deg. F. (370 deg. C.), which is unusually high for valves of this size; the fluid might be radioactive, necessitating extra precautions against leakage to the surrounding atmosphere; finally, very limited periods of access would be permissible during the operation of the plant, calling for maximum ease and simplicity of maintenance. The exacting nature of the service is reflected in the testing procedure, which included radiographic examination of all pressure castings; hydrostatic tests on casing and gate; seat tests under compressed air; and operating and tightness tests under full working temperature conditions. Eight 18 in. diameter cast steel wedge gate valves, with direct manual operation and anti-friction features, were supplied by the same company for similar conditions; also a considerable number of other types for low pressure services on the conventional or turbo-alternator side of the station.

The gas coolant lines are fitted with consolidated safety relief valves made by *Dewrance and Company, Limited*. These valves, one of which is shown in section in Fig. 20, are of high-lift high-capacity design specially constructed to give protection to equipment carrying gases and vapours. The single-ring blow-down adjustment controls blow-down only. Since this adjustment is not dependent upon multiple rings, it cannot affect lift and capacity by disturbing the area of the secondary annular orifice. It therefore ensures a constant and high capacity regardless of adjustments that are made or neglected on the plant. Dewrance large-bore parallel-slide valves are also installed in the gas coolant lines. These are of standard pattern but with specially designed glands, which can be repacked while the valves are under fluid pressure; special packing is used as specified

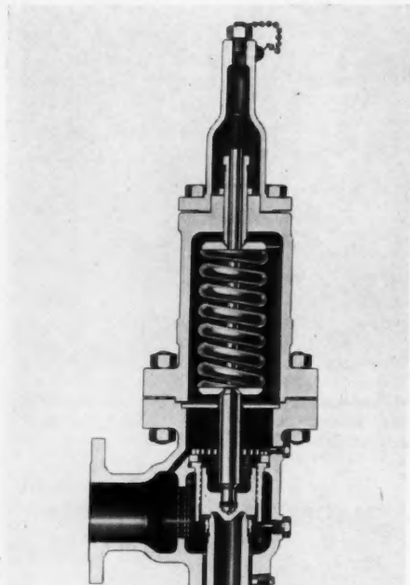


Fig. 20 Sectional view of a Dewrance safety relief valve used in the Calder Hall coolant lines.

by the U.K.A.E.A. The same company were responsible for the supply of heat-exchanger mountings and parallel slide valves for the steam and feed lines. The mountings include Dewrance consolidated safety valves of the Maxiflow pattern; these incorporate valve-heads of Thermodisc design, a special feature intended to prevent distortion of the actual seating face and consequent leakage. The bronze water gauges are sleeve packed and fitted with Dewrance patent bi-colour illuminators, which provide accurate and instantaneous readings of the boiler water level, with the steam and water spaces appearing to the observer a brilliant red and vivid green respectively.

In addition to other equipment described above, *Hopkinsons Limited* contributed a wide variety of valves. These included parallel-slide valves, ranging in size from 1 in. to 28 in. bore, some of the larger sizes being equipped with electrical valve controls. Other large valves supplied by this company are combined stop and isolating valves of 10 and 12 in. bore; 12 in. bore automatic exhaust valves and 20 in. bore relief valves of deadweight type. These deadweight valves, one of which is shown in Fig. 21, serve for dumping steam to atmosphere. In addition, a considerable number of Hopkinsons non-return valves, "Uniflow" slide valves and "Nolos" slide-valve steam traps are installed for various duties.

Pumps

The circulation of water through the secondary circuits of the Babcock and Wilcox heat exchangers is effected by 16 high-pressure and 16 low-pressure pumps, arranged in pairs with one operating and one standby unit in each category. The sub-contractors for the pumps were *Mather and Platt, Limited*, and *Hayward Tyler and Company, Limited*. In all, for both "A" and "B" stations, Hayward Tyler are supplying 34 glandless circulating pumps, one of which is illustrated in Fig. 22. They have been developed for pumping dangerous or expensive liquids and also for liquids in high-pressure systems as at Calder Hall.

Since both pump and motor are contained in a pressure shell, leakage to atmosphere is effectively prevented. No rotating seals of any kind are employed. Apart from the absence of leakage, these pumps have several other features.

Fig. 19 One of 16 Blakeborough 54 in. diameter power-operated wedge gate valves for the Calder Hall "A" station. Operated remotely, they serve to isolate sections of the coolant gas circuit, as when a blower or heat exchanger is to be inspected.

The inclusion of both pump and motor in a rigid pressure shell, mounted in a vertical position, eliminates problems of alignment. No baseplate is necessary, since the whole unit can be suspended from above or supported on the suction and discharge flanges. When the pump is at rest the pressure on both ends of the shaft is equal, so that, when starting, there is no thrust-bearing drag to overcome. Both thrust and journal bearings are of the tilting-pad type employing respectively a disc and sleeves of plastics material running against stainless-steel pads. These bearings are water lubricated, do not employ stuffing boxes and require a minimum of attention. They are capable of running for several years without maintenance or adjustment. Similar units are also being developed to pump liquid metals in reactor cooling or heat-exchange systems.

Charging and Discharging

Many of the items we have discussed so far have been merely variations on familiar engineering themes, though often fairly remote variations. Now that we come to consider the reactor and its associated equipment, we enter a region in which little is familiar, and much is unique. Fig. 23 shows the charging and discharging deck of No. 1 reactor; nothing similar will be found in a conventional power station, and 10 years ago few engineers, if any, could have guessed at its purpose. Primarily, it is concerned with the handling of fuel elements and the siting of the reactor's control-rod gear. The company which has been mainly concerned with the arrangements for charging and discharging the reactors is *Strachan and Henshaw Limited*.

The vertical channel system of the Calder Hall

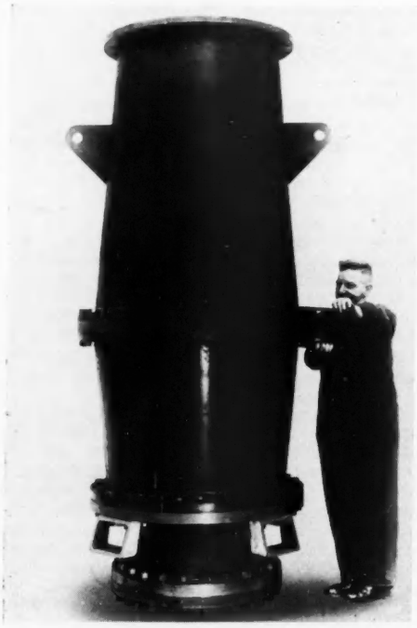


Fig. 21 Hopkinson 20 in. deadweight safety valve, one of several for dumping steam to atmosphere.

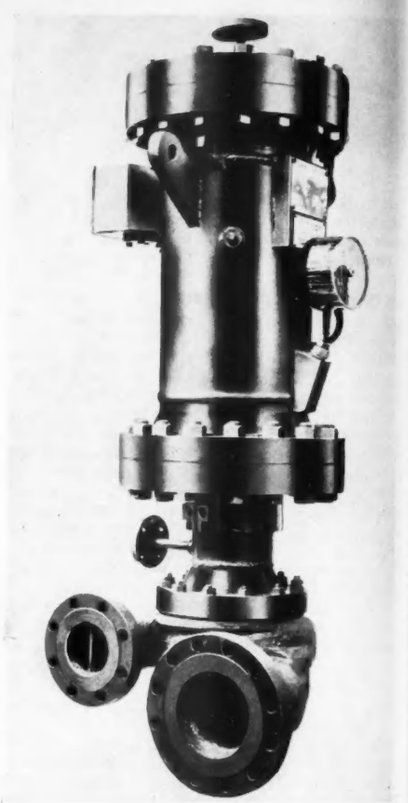
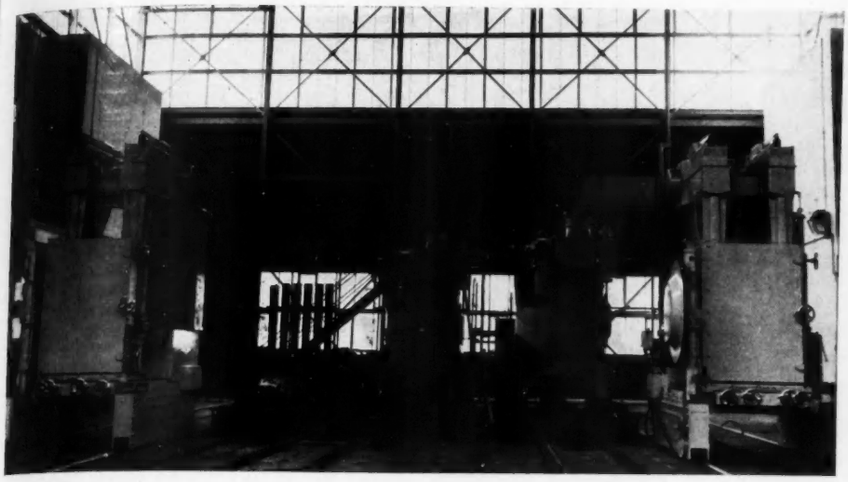


Fig. 22 Hayward Tyler glandless pumps, which serve to circulate water through the heat exchanger, are contained together with their associated motors in a pressure shell. They are designed to run for several years without maintenance.

reactors, in which the channels are blind at the bottom, makes it necessary to carry out the charging and discharging operations from the top end. The elements are lowered into position, and also removed, one at a time quickly and gently. For this purpose four machines are used, two for charging and two for discharging. Each machine is electrically propelled and equipped with a winch for handling the elements, which are accommodated in a removable magazine or basket containing a sufficient number to fill four channels. The winch is driven by a reversing motor having a wide range of controlled speeds, thus permitting an operating speed of 175 ft. per minute, and also creep speeds at the extremities of motion. An electrically operated grab is fitted to the end of the hoist cable. This also incorporates the necessary electrical cores for operation and remote indication; signals show, for example, whether the grab is open or closed, if it is in contact with an element, and whether or not an element is being carried by the grab. Indication is also given of grab depth, of slack cable and of magazine position. Numerous safety devices are incorporated to



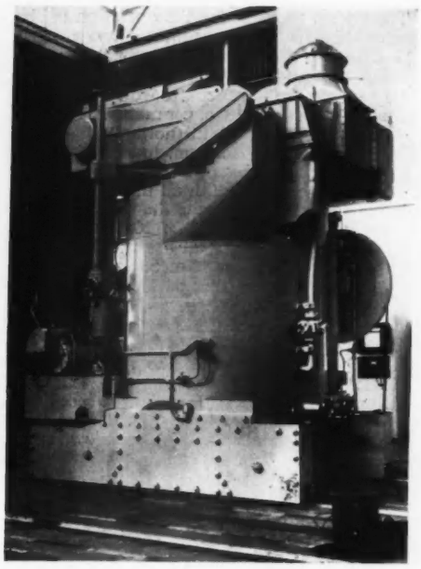


Fig. 23 (above) Charging deck of No. 1 reactor. The fuel channels required special charging and discharging machines, which were the responsibility of Strachan and Henshaw Ltd.

Fig. 24 Fuel element discharging machine. Unlike the charging machines to which they are generally similar, the discharge machines are fitted with considerable shielding since they are designed to carry the radioactive spent fuel elements.

prevent mal-operation; for instance, in the event of slack cable or over-tension the motor is automatically stopped. The magazine is moved laterally one pitch between elements. The appearance of the machines is indicated in Fig. 23. The two kinds are practically identical except that the discharge machine incorporates considerable shielding, since the spent elements are radioactive. Fans circulate coolant through an external heat exchanger, to ensure that the fuel-element temperature is kept to a safe value. A discharge machine is illustrated in Fig. 24. The operator rides on the machine in a seated position with grouped levers and indicators.

To enable the machines to command the whole of the vertical channels, a series of parallel steel rails is provided on the charging floor linking up with an electrically-driven traverser at one end so that any track is made available to any machine. When a magazine of a discharge machine is full of spent elements, it travels to the traverser, and its place over the channel is taken by the charge machine. The traverser moves the discharge machine over a circular well with heavy slide door, and when this has been moved aside and the shielding removed from the underside of the machine, the magazine is lowered down the well to ground level where it is deposited in a heavy wheel-mounted cast-iron flask containing water. In this thick-walled container the elements are transported to the storage pond. The whole area of the charging floor is served by a 64 ft. span overhead crane with twin hoisting motions of 7½ and 1 ton capacity, with variable speed control. The duty of the crane is to handle charge plugs, guide chutes, shield boxes and other items.

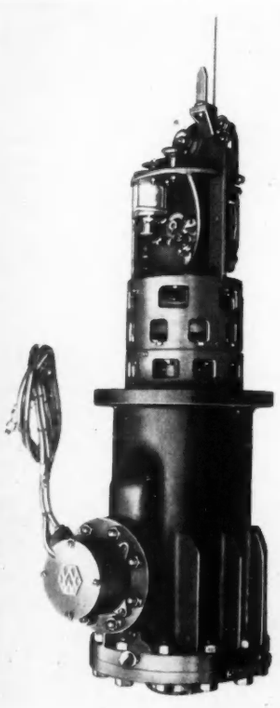


Fig. 25 Metropolitan-Vickers control-rod actuating mechanism. Coarse and fine control is provided and shut-off is effected by gravity fall of the rods.

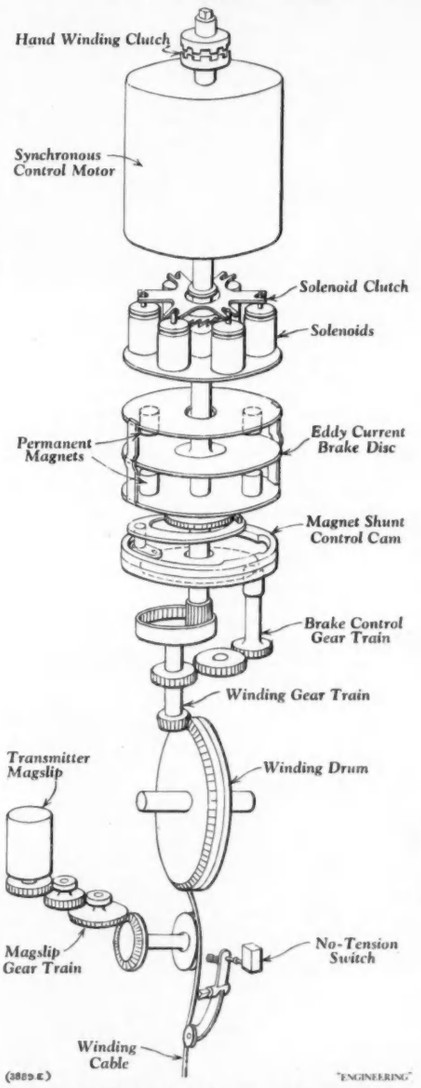


Fig. 26 Simplified exploded diagram of the actuating mechanism. Restricted space and the absence of oxygen and water vapour excluded normal lubricants, so molybdenum disulphide treatment was used.

Control Rod System

The control-rod system for the reactors at Calder Hall was developed by the *Metropolitan-Vickers Electrical Company Limited* for the U.K.A.E.A. over a period of several years, and the present design provides failure to safety under all conditions consistent with maximum reliability of operation. The actuating mechanisms, 60 of which have been supplied for each of the two piles in the "A" station, combine the functions of control and shut-off with the rods operating in vertical channels, as distinct from the separate control and shut-off rods of such reactors as BEPO. Vertical operation of the rods permits the use of a gravity fall for shut-off. Controlled braking is used so that a high launching speed can be attained with slow touchdown.

Each actuating mechanism is designed to work within the carbon dioxide coolant circuit pressurised to 100 lb. per sq. in. and shielded from neutron bombardment. Electrical connections are brought through the cast-steel pressure vessel to atmosphere. Severe space limitations were imposed on the design of the mechanism. The control-rod assembly weighs 130 lb. with an operational travel of 21 ft. and is suspended by a special low-cobalt flexible stainless-steel cable edge-wound between the side cheeks of a drum. Owing to the exclusion of oxygen and water vapour under operating conditions, a particularly difficult lubrication problem arises. This has been solved by the use of a dry lubricant in the form of a molybdenum disulphide (MoS_2) treatment. The use of normal oils is undesirable and graphite lubrication is unsuitable in the absence of water vapour.

The system provides for the operation of the control rod actuating mechanisms in two groups: (1) coarse—up to 60 actuating mechanisms; and (2) fine—up to 4 actuating mechanisms. For coarse operation three control-rod speeds are available: (1) in (fast) 50 in. per minute maximum (2·1 cm. per sec.); (2) in (normal) 5 in. per minute maximum (0·21 cm. per sec.); and (3) out (normal) 0·5 in. per minute maximum (0·021 cm. per sec.). With all the rods moving together the out speed limits the maximum rate of release of reactivity to 2×10^{-6} per second. For fine manual control an approximate maximum in and out rod speed of 50 in. per minute is possible. During the period of commissioning only, fast speeds in and out are made available by the incorporation of special test equipment. The shut-off performance of each rod is in accordance with the following conditions: (1) initial acceleration not less than 2 ft. per sec. per sec.; (2) maximum speed 4 ft. per sec.; (3) a travel of 18 ft. 6 in. in a time not greater than 5 seconds; and (4) touchdown speed not greater than 6 in. per sec.

The actuating mechanism is shown in Fig. 25 with a simplified functional diagram in Fig. 26. A synchronous driving motor of the variable-reluctance type is employed. It has a three-phase wound stator, Class H insulated, and an unwound rotor. This type of motor was chosen to meet the following requirements: (1) synchronous operation; (2) positive holding torque at standstill; (3) no brushgear, in order to give greater reliability; (4) high torque to volume ratio; (5) ability to work in an ambient temperature up to 100 deg. C.; and (6) ability to run at low speed (this allows a small gear ratio to be used so that back driving is possible when the rod is released on shut-off).

A solenoid clutch is fitted between the motor shaft and the remainder of the mechanism. Its purpose is to disengage the rotor of the motor from the system, thereby reducing the inertia to be overcome during shut-off. The clutch is operated by six solenoids energised from the same supply as the motor. Should the rotor of the motor fail to be disengaged when the supply is opened then a shut-off action will still result owing to the back driving of the de-energised motor. If there is loss of drive, an emergency winding handle can be attached which mechanically engages the clutch.

An eddy-current brake provides a controlled fall of the rod. It consists of two sets of permanent magnets with alternatively opposed north and south poles. An eddy-current copper-clad steel disc rotates in the air gap between the magnets. The braking torque on the disc is controlled by varying the air-gap magnetic flux with a magnetic shunt mechanically operated from a cam. The correct rate of fall under shut-off conditions is programmed by the profile of the cam. The drive from the motor is via single-stage spur gearing and right-angle bevel gears, giving a total reduction of 20 to 1.

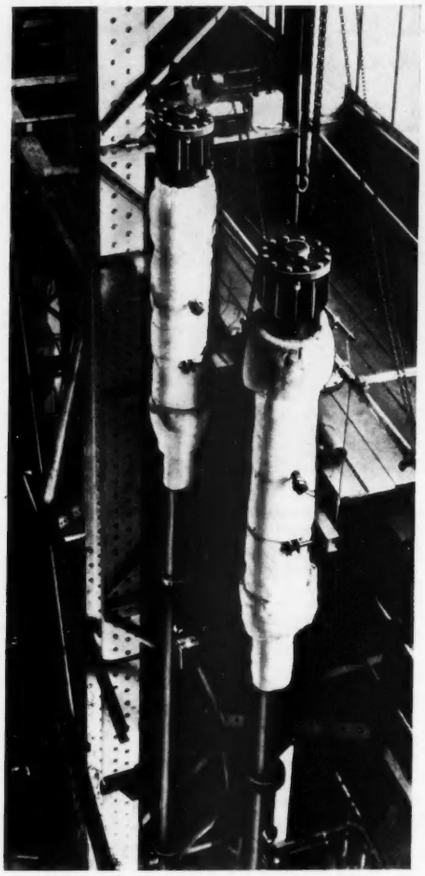
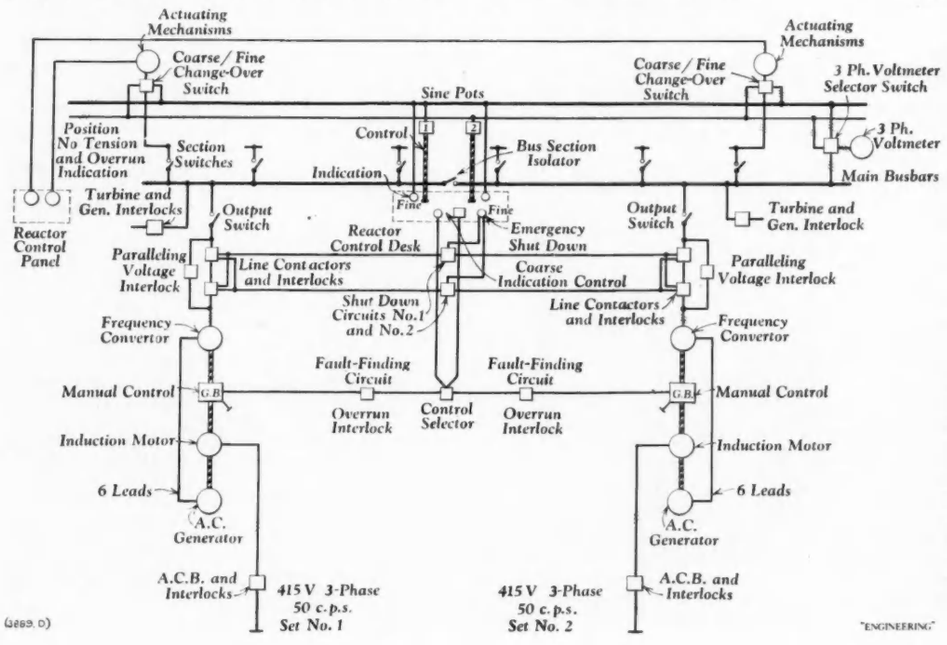


Fig. 27 (above) Control-rod actuating mechanisms seated on test pressure vessels, lagged to simulate the thermal effects of the biological shield. The units are designed to work within the reactor coolant circuit, where the gas pressure is 100 lb. per sq. in.

Fig. 28 (below) Schematic layout of control-rod operating system. It provides for the raising and lowering of the control rods by variation in frequency and phase sequence of the supplies to the actuating-mechanism drive motors.



Linear measurement of the rod position is provided by a transmitter magslip driven by a gear train from a cable-driven measuring wheel. A lever-operated switch with a follower wheel on the winding cable detects "no-tension." This switch is used in conjunction with a second switch operated by the magnet shunt control cam to detect "overrun or lost rod." The second switch is also used to check that the cam is correctly set.

After tests had been completed on individual components, extensive life tests were carried out on two actuating mechanisms which were run in an atmosphere of pure dry carbon dioxide with not more than 0·01 per cent. by volume of oxygen impurity at a pressure of 100 lb. per sq. in. Fig. 27 shows the actuating mechanisms seated on the test pressure vessels, lagged to simulate the thermal effects of the biological shield. Heating was applied corresponding to the heat flow up a charge tube. The actuating mechanisms were run for successive tests at the highest rod speed of 50 in. per minute and reversed automatically at the top and bottom of the rod travel. During the tests the following main points were studied: wearing properties of molybdenum disulphide treated gears and bearings, temperature rises, effects of thermal cycling, and the functional operation of components. Special measuring techniques were developed to obtain this information without opening up the actuating mechanism.

The control system is shown diagrammatically in Fig. 28. It provides for the raising and lowering of the control rods by variation in frequency and phase sequence of the three-phase alternating-current supplies to the driving motors of the actuating mechanisms. A range of frequencies 0 to 1·3 cycles per second, with a constant voltage of 40V r.m.s., is employed. The zero-frequency condition is used for holding the rods. Coarse and fine control supplies to any of the actuating mechanisms are selected by means of changeover switches mounted in distribution cubicles. These switches are connected to the main and auxiliary busbars to which are fed coarse and fine supplies respectively.

The coarse supply is generated by one of two identical frequency converter sets, as illustrated in Fig. 29, the other set being purely for standby duty. Operation of these sets is carried out from a machine operator's control desk. Position control of the coarse rods, together as a group, is provided by means of a control switch and a magslip indicator giving rod travel in accordance with a signal transmitted from the frequency converter set. Fine control supplies are provided by two sine-potentiometers mounted in the cubicles shown in Fig. 30. Each sine-potentiometer is basically a resistor chain fed by direct current and tapped to give a sinusoidal distribution of potential. The tapping points are taken out to studs on a faceplate from which three sets of brushes pick off an output three-phase supply at a frequency equal to the rate of rotation of the brushes. Position control of the fine rods is carried out at the reactor control desk by means of manual drives to the sine-potentiometers. Rod travel is given by M-type indicators operating from the outputs of the sine-potentiometers. A three-phase voltmeter was developed to give a direct reading of the equivalent r.m.s. voltage down to zero frequency; it can be seen in Fig. 30, being the larger of the two instruments. The voltmeter employs a three to two-phase transformation, thereby requiring only two moving-iron elements on the same shaft.

Each frequency converter set consists of

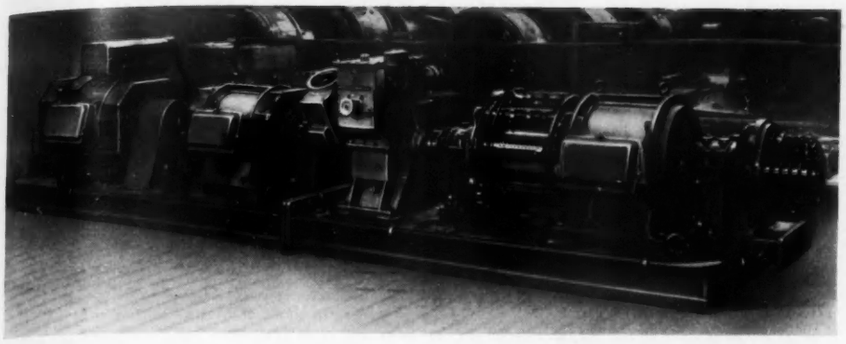


Fig. 29 Frequency converter set on test. Coarse control is obtained by a supply generated by one of two identical frequency converter sets, one being a standby.

a 37·5 h.p. induction driving motor, a 22 kVA salient pole alternating-current generator, a differential gearbox and a 19·4 kVA frequency converter mounted in line on a common bedplate.

Fig. 30 Fine-control power supplies are provided by two sine-potentiometers mounted in cubicles.

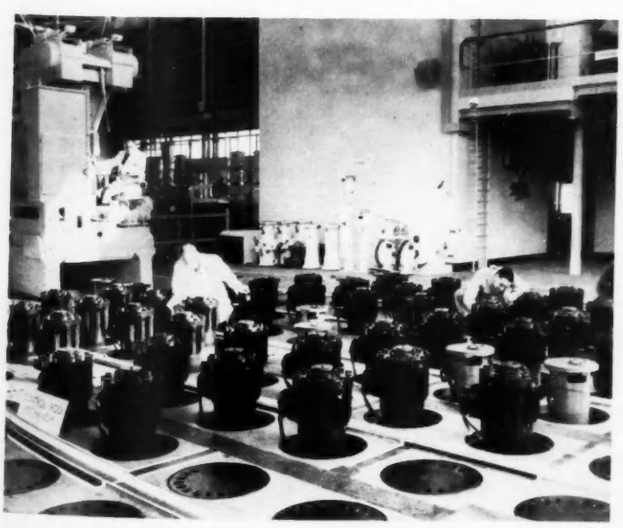


Fig. 31 Control-rod actuating mechanisms in position on the pile vault roof of No. 1 reactor.

The motor is started direct-on-line by closing the 415 volt circuit breaker. It is designed to deliver full load torque even if the terminal voltage falls to 50 per cent. of its normal value. Furthermore, the alternating-current generator is excited from the 50V station battery which enables the stored energy of the frequency converter set to maintain continuity of the output supply for the maximum time when running down due to fault conditions on the 415V alternating-current supply.

The frequency converter has no stator winding, is rotor fed and gives a three phase output of 40V r.m.s. with frequencies 0 to 1·3 cycles per second. Its input supply from the alternating-current generator is taken to the rotor through six sliprings. A three-phase output is taken from brush arms arranged round the commutators. The power required to drive it (equal only to its friction and windage losses) is supplied by the induction motor through the differential gearbox. If the input and output shafts of the gearbox are rotating at the same speed, the frequency converter is running in synchronism with the alternating-current generator and the output derived from its commutator is of zero frequency. The values of current drawn from the three output brushes will depend on the positional relationship between the rotors of the two machines. If a decrement of speed is fed into the differential gearbox through its pilot motor section (described later) the frequency converter runs sub-synchronously with respect to the alternating-current generator, and a three-phase supply can be drawn from its commutator of frequency corresponding to the difference in rotational speeds of the two machines. If an increment of speed is fed into the gearbox, the frequency converter will run super-synchronously with respect to the alternating-current generator; again a three-phase supply will be available at its commutator with a frequency corresponding to the difference in rotational speeds of the machines, but having a phase sequence which is the reverse of that obtained with sub-synchronous running. The voltage of the output is independent of the frequency converter speed and is determined purely by the alternating-current generator excitation.

The system is designed to move the rods in when the frequency converter is running sub-synchronously so that in the event of a failure of drive to the frequency converter the system will fail to safety by moving the rods in. Any normal three-phase relationship between the zero frequency voltages at the frequency converter output terminals can be achieved when the machine is running synchronously by operating the differential gearbox to bring the rotors of the alternating-current generator and frequency converter into the correct relative position; this relationship is partly dependent on the load.

The differential section of the gearbox is of the sun-and-planet epicyclic type. The drive to the third member of the differential is through an irreversible worm from a small pilot motor via one of three permanently meshed gear ratios selected by individual electromagnetic d sc clutches having stationary windings. An electromagnetic brake is applied to the third member shaft when no drive is selected by the coarse control switch on the reactor control desk. An indicating dial attached to the main gearbox housing indicates the position of the differential cage which can be manually moved over a restricted angle to facilitate paralleling of the two frequency converter sets during changeover. Indication of the coarse rod travel is also transmitted from the differential gearbox to the reactor control desk.

In order to ensure continuity of the coarse control supply at the main busbars during changeover of the frequency converter sets it is necessary to parallel the incoming frequency converter set before transferring the load. The line contactors are interlocked to ensure correct paralleling of the incoming set and the control selector switch is automatically interlocked so that the incoming set must be carrying the load before the outgoing set is tripped off.

A magslip indicator associated with each actuating mechanism shows the position of each rod. The indicator also carries two lamps which indicate "no-tension" and "lost or overrun rod" which are operated from the switches in the actuating mechanisms via fault finding relay circuits. Two safety circuits detect the following: (1) faults which necessitate de-energising the actuating mechanisms and dropping the rods, so initiating a shut-down of the reactor; and (2) faults which prevent further movement of the rods.

An emergency shut-down of the reactor is initiated from the emergency push button on the reactor control desk or from one of the shut-down circuits. All the line contactors and 415V circuit breakers are opened, thus removing the control supply from the main busbars and thereby de-energising the actuating mechanisms so that the rods give shut-off action. At the same time the sine-potentiometer supply is tripped so that the fine rods also give a shut-off action. The main turbines and alternating-current generators are tripped from relays operating on under-voltage at the main busbars so preventing the turbines being motored. Hence a complete shut-down of the plant occurs.

Fig. 31 shows the actuating mechanisms fitted to the pile cap of reactor No. 1 at Calder Hall "A" power station; they can be seen projecting above the level of the charging and discharging deck.

(A list of contractors and sub-contractors will appear at the end of the article, which is to be continued.)

★ ★ ★

HIGH-TEMPERATURE SAFETY FLUX

Non-corrosive safety fluxes based upon resin tend to carbonise at comparatively low temperatures when used in the soft soldering operation. Consequently, they may give rise to difficulties when used for soldering commutators or other work where the relatively high operating temperatures necessitate the use of a solder having a melting point above the normal tin-lead range.

After investigating this problem, the research department of Fry's Metal Foundries, Limited, Tandem Works, Merton Abbey, London, S.W.19, have introduced a new product to which they have given the name Alcho-re soldering fluid, type S.64. This substance permits of the use of an operating temperature of from 50 to 100 deg. C. above the carburising point of orthodox resin fluxes. In this manner soldering is completed without flux carbonisation, and the risk of dewetting and dry joints is reduced.

The Seismitron, which has been designed to enable the probability of rock falls occurring to be detected aurally.

ELECTRONIC DETECTION OF ROCK FALLS

The prediction of rock falls, which are one of the major causes of accidents in tunnelling and mining work, is the object of a new instrument known as the Seismitron. This has been designed in the Research Department of the Liberty Mutual Insurance Company of America and is now being employed on the Snowy Mountains hydro-electric scheme in Australia, of which an account has appeared in ENGINEERING of August 24, page 232, and September 28, page 394. It is expected that the two concluding articles will be published before the end of the year.

Rock falls are usually preceded by movements which are at first inaudible to the human ear; and when these movements do become audible, as occurs very shortly before the fall, it is often too late to take safety measures. A further problem is that, while it would be easy to amplify the noises due to rock movement by electronic means, it has also been found difficult to exclude those due to other electrical equipment.

These drawbacks, it is claimed, are overcome by the Seismitron, of which an illustration appears on this page. This instrument, which has been described as an electronic stethoscope, consists of a transducer and a pair of earphones, which are carried in a case. In operation, the transducer is placed in a drilled hole well within the rock formation and in close contact with it. Any movement of the rock, however slight, is then communicated to the transducer, thus causing the crystal inside it to move as little as 0·000001 in. or less. This movement is translated into electrical impulses, which are amplified and transmitted to the microphone so that they can be detected by the ear.

The nature of the sound varies with the geological formation of the rocks and ores present; and the successful use of the instrument depends on the operator's knowledge of the geology of the area and his experience in reading the signals. Observation, therefore, depends on regular tests which, it is recommended, should be recorded on charts, each of which represents a key point in drives or tunnels.

By using crystal instead of magnetic earphones, together with an amplifier of very high gain, the Seismitron can also be employed for detecting termites in timber and for locating trapped miners.

The instrument can be hermetically sealed, but has the disadvantages that it is fragile and expensive. Moreover, the signals cannot be recorded or indicated on a dial.

NOTICES OF MEETINGS

Association of Supervising Electrical Engineers

BRIGHTON
"New Light Sources," by G. V. McNeill. Brighton, Hove and District Branch. New Imperial Hotel, First-avenue, Hove. Wed., Oct. 31, 7.30 p.m.

CROYDON
"Power Factor Correction," by J. R. Arthur. South London Branch. Half Moon Hotel, Broad Green, Croydon. Thurs., Nov. 1, 8 p.m.

LIVERPOOL
"Modern Railway Signalling," by J. Sulston. Liverpool Branch. Liverpool Engineering Society, 9 The Temple, 24 Dale-street, Liverpool. Fri., Nov. 2, 7.30 p.m.

NOTTINGHAM
Film of the 1956 Electrical Engineer's Exhibition. Nottingham Branch. Mechanics' Institute, Trinity-square, Nottingham. Wed., Oct. 31, 7.15 p.m.

British Institution of Radio Engineers

LONDON
Annual General Meeting, at 6 p.m. Presidential Address of G. A. Marriott, at 7.15 p.m. London Section. London School of Hygiene and Tropical Medicine, Keppel-street, W.C.1. Wed., Oct. 31, 6 p.m.*

CARDIFF
Annual General Meeting. "Applications of Transistors to Radio Reception," by L. E. Jansson. South Wales Section. Cardiff, College of Technology, Cathays Park, Cardiff. Wed., Oct. 31, 6.30 p.m.

MALVERN
"Principles of the Light Amplifier and Allied Devices," by Dr. T. B. Tomlinson. South Midlands Section. The Winter Gardens, Malvern. Thurs., Nov. 1, 7 p.m.

MANCHESTER
"Electronics Applied to Physiology," by H. W. Shipton. North Western Section. College of Technology, Sackville-street, Manchester, 1. Thurs., Nov. 1, 6.30 p.m.

British Interplanetary Society

LONDON
"The Atmosphere of Mars," by Dr. R. M. Goody. Caxton Hall, off Victoria-street, S.W.1. Sat., Nov. 3, 6 p.m.

Building Centre

LONDON
Films on "Changing Practices in Building" and "Building Houses." Wed., Oct. 31, 12.45 p.m.

Chemical Society

BRISTOL
"Physical Properties of High Polymers in Relation to Their Chemical Structure," by Professor G. Gee. Bristol Branch. Chemical Department, The University, Bristol. Thurs., Nov. 1, 7 p.m.

DUBLIN
"Birth and Death of Free Radicals in Polymerisation," by Dr. C. H. Bamford. Irish Republic Branch. Chemistry Department, Trinity College, Dublin. Fri., Nov. 2, 7.45 p.m.

SOUTHAMPTON
"Some Applications of Radiochemistry," by Dr. R. Spence. Southampton Branch. Chemistry Department, The University, Southampton. Fri., Nov. 2, 5 p.m.

Illuminating Engineering Society

GLASGOW
"Design To-day," by A. Maynard. Glasgow Centre. Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank-crescent, Glasgow, C.2. Thurs., Nov. 1, 6.30 p.m.

HULL
"Problems of Shop and Store Lighting," by K. C. White. Leeds Centre. Offices of the Yorkshire Electricity Board, Ferensway, Hull. Mon., Oct. 29, 7 p.m.

NOTTINGHAM
"Road Vehicle Lighting," by J. H. Nelson. Nottingham Centre. Electricity Service Centre, Smithy-row, Nottingham. Thurs., Nov. 1, 6 p.m.*

Incorporated Plant Engineers

LEEDS
"Commonsense Fuel Economy," by C. W. Peters. West and East Yorkshire Branch. The University, Leeds. Mon., Oct. 29, 7.30 p.m.

Institute of British Foundrymen

HANLEY
"Core Assembly Methods," by E. H. Beech. Stoke Section. Stipendiary Court, Hanley. Thurs., Nov. 1, 7.30 p.m.

Institute of Industrial Supervisors

BRADFORD
Volkswagen film "On Their Own Initiative." Bradford and Dewsbury Section. Technical College, Bradford. Thurs., Nov. 1, 7.30 p.m.

KIDDERMINSTER
"Communications," by J. Fairhead. Kidderminster Section. Offices of Brintons Ltd., Exchange-street, Kidderminster. Wed., Oct. 31, 7.30 p.m.

Institute of Marine Engineers

LONDON
"Modern Marine Steam Turbines," by J. H. Gooch. Junior Lecture. Poplar Technical College, E.14. Wed., Oct. 31, 7.15 p.m.
"Metallurgy in Marine Engineering," by Dr. J. E. Garside. Junior Lecture. West Ham College of Technology, E.15. Thurs., Nov. 1, 7 p.m.

LIVERPOOL
"Boiler Water Treatment," by J. D. Skelly. Junior Lecture. Merseyside and North Western Section. Riversdale Technical College, Liverpool. Wed., Oct. 31, 5.30 p.m.

Institute of Marine Engineers and Institution of Naval Architects

PORTSMOUTH
"Cavitation of Ships' Propellers," by A. F. Weeks. Southern Joint Branch. College of Technology, Anglesey-road, Portsmouth. Tues., Oct. 30, 7.30 p.m.

Institute of Metals

LONDON
"Primitive Metallurgy," by Professor F. C. Thompson. London Local Section. Royal School of Mines, South Kensington, S.W.7. Thurs., Nov. 1, 7 p.m.

Institute of Road Transport Engineers

EXETER
Open Meeting. Western Centre. Rougement Hotel, Exeter. Wed., Oct. 31, 7.30 p.m.

Institute of Welding

LONDON
Joint meeting with the Netherlands Welding Society: Presidential Address by Sir Charles Lillicrap. Various papers for reading and discussion. Institution of Civil Engineers, Great George-street, S.W.1. Thurs., Nov. 1, 9.30 p.m.
Various papers for reading and discussion; and Dutch film on "Men and Steel." Institution of Mechanical Engineers, 1 Birdcage-walk, St. James's Park, S.W.1. Thurs., Nov. 1, 2 p.m.
Various papers for reading and discussion. Institution of Civil Engineers, Great George-street, S.W.1. Fri., Nov. 2, 9.30 a.m. and 2 p.m.

Institution of British Agricultural Engineers

BIRMINGHAM
"Preparation and Handling of Feeding Stuffs," by J. R. Robertson. West Midlands Centre. Chamber of Commerce, 95 New-street, Birmingham. Mon., Oct. 29, 7.30 p.m.

Institution of Civil Engineers

LONDON
Symposium on "Side Spillways." General reporter: P. O. Wolf. Hydraulics Division. Tues., Oct. 30, 5.30. p.m.*
"Conservation of Natural Resources." III.—"Conservation of Land," by Professor L. Dudley Stamp. Thurs., Nov. 1, 5.30 p.m.*
Presidential Address by H. J. F. Gourley. Tues., Nov. 6, 5.30 p.m.*

MANCHESTER
"Effluents and Drainage at Windscale Works," by F. R. Farmer. North Western Association. Engineers' Club, Albert-square, Manchester. Thurs., Nov. 1, 6.30 p.m.

Institution of Electrical Engineers

CHESTER
"Domestic Heat Pump Installations," by G. O. McLean. Mersey and North Wales Centre. Town Hall, Chester. Mon., Oct. 29, 6.30 p.m.

LEEDS
Discussion on "Teaching of High-Voltage Testing," opened by Dr. D. A. Jones. Education Discussion Circle Meeting. North Midland Centre. The University, Leeds. Tues., Oct. 30, 6.30 p.m.

WORCESTER
"Automation and Its Social and Economic Implications," by L. Landon Goodman. South Midland Centre. Worcester Sports Club, Hilton-road, Worcester. Mon., Oct. 29, 6 p.m.

Institution of Engineering Designers

NEWCASTLE-UPON-TYNE
"Design and Application of Centrifugal Pumps," by D. W.

The address and telephone number of the headquarters of each institution are given below. Meetings in the headquarters town are held there unless otherwise stated. Particulars for this column should reach the Editor not later than Monday morning in the week preceding the date of the meeting.

* An asterisk is placed where it is understood that tea is available prior to the time stated.

Association of Supervising Electrical Engineers, 23 Bloomsbury-square, London, W.C.1. (LANgham 5927.)
British Institution of Radio Engineers, 9 Bedford-square, London, W.C.1. (MUSeum 1901.)
British Interplanetary Society, 12 Bessborough-gardens, London, S.W.1. (TATe Gallery 9371.)
Building Centre, 26 Store-street, London, W.C.1. (MUSeum 5400.)
Chemical Society, Burlington House, Piccadilly, London, W.1. (REGent 0675.)
Illuminating Engineering Society, 32 Victoria-street, London, S.W.1. (ABBey 5215.)
Incorporated Plant Engineers, 48 Drury-lane, Solihull, Birmingham. (Solihull 3021.)
Institute of British Foundrymen, St. John Street Chambers, Deansgate, Manchester, 3. (Blackfriars 6178.)
Institute of Industrial Supervisors, 24 Albert-street, Birmingham 4. (Midland 6971.)
Institute of Marine Engineers, 85 The Minories, London, E.C.3. (ROYal 8493.)
Institute of Metals, 17 Belgrave-square, London, S.W.1. (BELgravia 3291.)
Institute of Road Transport Engineers, 69 Victoria-street, London, S.W.1. (ABBey 6248.)
Institute of Welding, 2 Buckingham Palace-gardens, London, S.W.1. (SLOane 9851.)
Institution of British Agricultural Engineers, 6 Buckingham-gate, London, S.W.1. (TATe Gallery 8589.)
Institution of Civil Engineers, Great George-street, London, S.W.1. (WHItehall 4577.)
Institution of Electrical Engineers, Savoy-place, Victoria-embankment, London, W.C.2. (TEMple Bar 7676.)
Institution of Engineering Designers, 38 Portland-place, London, W.1. (LANgham 8847.)
Institution of Heating and Ventilating Engineers, 49 Cadogan-square, London, S.W.1. (SLOane 3158.)
Institution of Mechanical Engineers, 1 Birdcage-walk, St. James's Park, London, S.W.1. (WHItehall 7476.)
Institution of Naval Architects, 10 Upper Belgrave-street, London, S.W.1. (SLOane 4622.)
Institution of Production Engineers, 10 Chesterfield-street, London, W.1. (GROsvenor 5254.)
Institution of Structural Engineers, 11 Upper Belgrave-street, London, S.W.1. (SLOane 7128.)
Junior Institution of Engineers, Pepys House, 14 Rochester-row, London, S.W.1. (VICtoria 0786.)
Leeds Metallurgical Society. Apply to Dr. P. Feltham, The University, Leeds, 2.
North East Coast Institution of Engineers and Shipbuilders, Bolbec Hall, Newcastle-upon-Tyne, 1. (Newcastle 20289.)
Reinforced Concrete Association, 94–98 Petty France, London, S.W.1. (ABBey 4504.)
Royal Aeronautical Society, 4 Hamilton-place, London, W.1. (GROsvenor 3515.)
Royal Institution, 21 Albemarle-street, London, W.1. (HYDe Park 0669.)
Royal United Service Institution, Whitehall, London, S.W.1. (WHItehall 5854.)
Sheffield Metallurgical Association, 66 Ringstead-crescent, Sheffield, 10. (Sheffield 62144.)
Sheffield Society of Engineers and Metallurgists, University of Sheffield, St. George's-square, Sheffield, 1. (Sheffield 24071.)
Society of Engineers, 17 Victoria-street, London, S.W.1. (ABBey 7244.)
Society of Industrial Radiology, 2 Townswood-terrace, Barking-side, Essex. (HAInhault 5488.)
Society of Instrument Technology, 20 Queen Anne-street, London, W.1. (LANgham 4251.)

Coleman. North East Branch. Northern Architectural Association, 6 Higham-place, Newcastle-upon-Tyne. Mon., Nov. 5, 7.15 p.m.

Institution of Heating and Ventilating Engineers

GLASGOW
"Medium-Pressure Hot Water," by T. H. F. Holman. Scottish Branch. Scottish Building Centre, 425 Sauchiehall-street, Glasgow, C.2. Tues., Oct. 30, 7 p.m.

Institution of Mechanical Engineers

LONDON
Discussion on "Selection and Training of Engineering Designers." Industrial Administration and Engineering Production Group. Wed., Oct. 31, 6.45 p.m.*
"A Review of the Performance of Exhaust Systems for Gas-Turbine Aero-engines," by P. F. Ashwood. Meeting in conjunction with the Internal Combustion Engine Group. Fri., Nov. 2, 6 p.m.*

ABERDEEN
"The Pressurised Water Reactor as a Source of Heat for Steam Power Plants," by Dr. J. M. Kay and F. J. Hutchinson. Scottish Branch. Robert Gordon's College, Aberdeen. Fri., Nov. 2, 7.30 p.m.

GLASGOW
"The Pressurised Water Reactor as a Source of Heat for Steam Power Plants," by Dr. J. M. Kay and F. J. Hutchinson. Scottish Branch. Royal Technical College, Glasgow. Thurs., Nov. 1, 7.30 p.m.

LIVERPOOL
"A Criticism of the Technical Education of Recently Qualified Engineers," by P. P. Love. North Western Branch. Liverpool Engineering Society, 9 The Temple, 24 Dale-street, Liverpool. Thurs., Nov. 1, 6 p.m.

NOTTINGHAM
"The Practical Application of Air Conditioning in Industry," by L. G. W. Gosden. East Midlands Branch. College of Arts and Crafts, Waverley-street, Nottingham. Wed., Oct. 31, 7.30 p.m.

Institution of Production Engineers

BRIGHTON
"Materials Utilisation," by F. G. S. English. London Section. Old Ship Hotel, Brighton. Tues., Oct. 30, 7 p.m.

GLASGOW
Open Discussion Meeting. Glasgow Section. Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank-crescent Glasgow, C.2 Thurs., Nov. 1, 7.30 p.m.

MANCHESTER
"Computor Controlled Machine Tools," by D. T. N. Williamson. Manchester Section. College of Technology, Manchester. Mon., Oct. 29, 7.15 p.m.

SHEFFIELD
Open Discussion Meeting. Sheffield Section. Grand Hotel, Sheffield. Mon., Oct. 29, 6.30 p.m.

Institution of Structural Engineers

BRISTOL
"Results of Experiments on Torsion in Concrete and Their Application to Design," by S. Armstrong. Western Counties Branch. New Engineering School, The University, Bristol. Fri., Nov. 2, 6 p.m.

PLYMOUTH
Chairman's Address by Lieut-Colonel R. Hazzledine. South Western Counties Branch. Duke of Cornwall Hotel, Plymouth. Thurs., Nov. 1, 7 p.m.

Junior Institution of Engineers

LONDON
Film Evening. Fri., Nov. 2, 7 p.m.*

Leeds Metallurgical Society

LEEDS
"Powder Metallurgy Applied to Mechanical Parts," by H. Davies. Large Chemical Lecture Theatre, The University, Leeds, 2. Thurs., Nov. 1, 7.15 p.m.

North East Coast Institution of Engineers and Shipbuilders

NEWCASTLE-UPON-TYNE
Parsons Memorial Lecture on "A Review of Naval Propulsion Engineering Progress in the Last Ten Years," by Vice-Admiral Sir Frank T. Mason. Literary and Philosophical Society's Lecture Theatre, Newcastle-upon-Tyne. Fri., Nov. 2, 6.15 p.m.*

Reinforced Concrete Association

LIVERPOOL
"Methods of Shuttering as they Affect the Design and Surface Finish of Concrete," by C. Parry. North Western Branch. Liverpool Engineering Society, 9 The Temple, 24 Dale-street, Liverpool. Wed., Nov. 7, 6.30 p.m.*

MANCHESTER
"Methods of Shuttering as they Affect the Design and Surface Finish of Concrete," by C. Parry. North Western Branch. College of Technology, Sackville-street, Manchester. Tues., Nov. 6, 6.45 p.m.*

Royal Aeronautical Society

LONDON
"Nuclear Power for Aircraft," by E. P. Hawthorne. Graduate's and Students' Section. Tues., Oct. 30, 7.30 p.m.

Royal Institution

LONDON
"Optics in Industry." III—"Composition," by Dr. A. C. Menzies. Tues., Oct. 30, 6 p.m.

Royal United Service Institution

LONDON
"The Ascent of Kanchenjunga," by Captain H. R. A. Streather. Wed., Oct. 31, 3 p.m.

Sheffield Metallurgical Association and Sheffield Society of Engineers and Metallurgists

SHEFFIELD
"Use of Oxygen in Iron and Steel Making," by J. L. Harrison. The University, St. George's-square, Sheffield. Tues., Oct. 30, 7 p.m.

Society of Engineers

LONDON
"Gas Turbines in Theory and Practice," by D. F. Collins. Geological Society, Burlington House, Piccadilly, W.1. Mon., Nov. 5, 5.30 p.m.*

Society of Industrial Radiology

GLASGOW
"Ultrasonics," by A. C. Rankine. Scottish Branch. Royal Technical College, Glasgow. Fri., Nov. 2, 7.45 p.m.

Society of Instrument Technology

LONDON
"Control Engineering and the Automatic Process Plant," by D. S. Townend. Meeting in conjunction with the Control Section. Manson House, 26 Portland-place, W.1. Tues., Oct. 30, 7 p.m.*

ATOMIC REVIEW

Plant and Manpower

"From modest beginnings on a disused airfield at Harwell, ten years ago, atomic energy is rapidly emerging as one of our most important industries." These words of Lord Citrine justly reflect the pride of the nation, and are a deserved tribute to the newest section of British engineering. "Has emerged" might have been more appropriate words for the chairman of the Central Electricity Authority to have used, since he had already received from the new industry competitive tenders for two complete nuclear power stations each of an output which may reach 300 MW. This coming of age so soon after its birth, and ahead of its powerful international rivals, does credit to British industry, for the effort which produced the tenders is widely based indeed. More than 250 firms have so far taken part in the development of nuclear engineering, and more are coming in all the time.

The problems these companies have to face are vast and complex, but the backing and encouragement they are getting—from the Atomic Energy Authority and now from the C.E.A.—is unparalleled in the growth of any industry, even in time of war. It should enable them to forge even further ahead of their competitors abroad. The reason is a simple one. Splitting the atom—brought about by the insatiable curiosity of scientists as much as by the needs of war—has become indispensable to the maintenance of Britain as a major industrial power. In the U.S. the annual consumption of energy per head of the population is equivalent to 8 tons of coal: in Britain the figure is only 4½ tons, and no significant leeway can be made up by increased coal production. Oil is a political risk and likely to remain so. The conclusion therefore is inescapable: nuclear engineering must continue to grow, and at a faster rate. The strength of the demand for its products at home will give it considerable competitive strength abroad. The export future of the industry is probably brighter than that of any other section of engineering.

British Nuclear Engineering

The magnitude of the development task has led to the pooling of the resources of major companies already well established in the supply of plant and equipment for the generation of electricity by conventional methods. Four separate industrial groups have been formed, each led by one of the heavy electrical plant manufacturers and including a boiler maker, a civil engineering contractor and in some cases a firm of consulting engineers. Other groups will doubtless be formed as the demand increases and more trained engineers become available. The training of necessary staff will take time, and may prove the major restriction of the rate of growth over the next few years. Apart from the supply of scientists and technicians with suitable background education there are limits to the facilities available for their training. So far, these have been provided mainly by the Atomic Energy Authority in their research establishments and experimental plants. The Central Electricity Authority will doubtless be in a position to take some of the load off the A.E.A. but the demand is likely to remain greater than the supply for some years. It is in this respect that the United States and the U.S.S.R. are at an advantage which could become decisive in the forthcoming competitive struggle for markets in under-developed or fuel-starved countries.

There are four existing groups and in addition nearly 250 companies are acting as sub-contractors to these groups, supplying instruments, special metals and alloys, pipe-work, pumps, valves, chemicals, glass-work, refractories and a host of other components and equipment. Very few large engineering companies have failed to react to the immense promise of the nuclear age. It is too early to say how many are employed on the manufacture of materials, components, equipment and plant. But as the capital cost per kilowatt of the first few nuclear stations is likely to be more than double the cost of conventional stations (i.e., twice £54·3 per kW) and as the total capacity of the first 12 stations included in the C.E.A.'s programme to 1965 may well exceed 3,600 MW, the turnover of the industry for home needs alone is likely to average £43 million a year. Assuming a gross output per man employed to be about £1,500 a year (probably a low figure) the average employment on C.E.A. work will be about 30,000. The tremendous requirement for designers, draughtsmen, estimating and contracts engineers is illustrated by Lord Citrine's remarks concerning the tenders submitted on October 1 by the four principal contracting groups for the first two power stations in the C.E.A. programme: "The selection of the successful tenders presents a tremendous task, probably the greatest of its kind that has yet been faced in British industry. The documents covering designs, specifications and the like, constituting a volume of paper several tons in weight, are now being examined by our engineers."

International Developments

Co-operation between companies is not confined to this country, nor indeed confined to national boundaries. The recently announced agreement between Mitchell Engineering Limited and AMF Atomics Inc. of New York, shows that co-operation can be international. Mitchell Engineering are engaged on three major contracts for A.E.A. and entered into this agreement—private industry's first international agreement—"for the joint design and construction of nuclear power plant in the Commonwealth and other countries."

Developments in the United States during the past 12 months have also been towards the establishment of a powerful nuclear engineering industry. In December of last year the United Sta es Atomic Energy Commission awarded the first major contract for the fabrication of reactor fuel elements to a private company. At that time a leading American industrialist, Mr. Charles Robbins, predicted that industry and the Government would spend 10,000 million dols. on the development and use of atomic energy in ten years: "The atomic industry is fast moving into private hands. Electric power companies in the United States have announced plans to build almost 1,000 MW of electric generating capacity within the next five years. By 1956, this will be tripled." Early this year the Un ted States Atomic Energy Commission issued a regulation designed to encourage private firms to begin atomic activities abroad. The deputy director of the Commission's Division of Reactor Development said recently that the United States Government had borne the main burden of nuclear development in its early phases because it considered the speeding up of the work to be in the national interest and because the initial financial burden was too great for any industrial concern. He added, however, that during the next 10 to 15 years it was the Government's earnest hope that a complete and self-sufficient nuclear industry would become established, free from major dependence upon the Government. "This would include not only the construction and operation of the power plants themselves but also the provision of all the necessary materials, components and services." Several decisive steps were taken to achieve this. The price of uranium as a processed mill product rather than as a raw material will be guaranteed by the United States Government as from 1962. Contracts aggregating 14 million dols. were signed with these private suppliers and cover five years' output of zirconium (used to clad fissionable materials in fuel elements). Similar steps are being taken for the production of

beryllium (a cladding and moderating material). Proposals have been invited from private firms for the production of uranium feed materials for the A.E.C's production plants, and for the design, construction and operation of chemical processing plants for the handling of irradiated fuel elements.

The response of American industry has been prompt, and the announcement earlier this month that six private electric power companies have set up a " technical appraisal task force on nuclear energy " suggests that American industry is unwilling to remain far behind in the nuclear generation of electricity. This is despite the availability of cheap hydro-generated power, natural gas and low-cost coal-fired stations. An account of the reason which led the American Machine and Foundry Corporation into nuclear engineering (" Setting up an Atomic Subsidiary," *Atoms for Peace Digest*, September 8, 1956) by the vice-president of AMF Atomics Inc., is a striking illustration of the commercial emphasis which is being placed in the United States on atomic plant production. It is also a useful guide to the various steps required to achieve this and to the many obstacles to overcome.

Problems of Atomic Plant Operation

A good many of the problems that arise in connection with the operation of atomic power plant are still so new that no complete solution has been found, in that those put forward are still highly controversial. Among these problems, the greatest and that of most universal concern is the health of the personnel employed in atomic establishments and the health of the residents in areas where they operate. Some, among them eminent and respected scientists, see a danger to health likely to become world-wide. This threat—which the most intimately concerned specialists tend to minimise—is examined below.

A Threat and a Contribution

Controversy rages and is likely to continue for years on the subject of the dangers of radiation. But the evidence that has come to light so far generally confirms that science is succeeding in the task defined by President Eisenhower when considering the broad significance of atomic developments as: " . . . to find the way by which the miraculous inventiveness of man shall not be dedicated to his death but consecrated to his life." The dangers to health considered here are not those created by the threat of war or by the repeated tests of atomic weapons, which are justly causing world-wide apprehension and concern. We are dealing only with the threats to health constituted by the peaceful and productive uses of atomic energy, and with the medical advances the by-products of nuclear plants have made and are making possible. A most comprehensive study of the subject was undertaken by a committee appointed by the Medical Research Council in March, 1955, at the Prime Minister's request. This committee's report, " The Hazards to Man of Nuclear and Allied Reactions," was submitted to the Government last June. Two panels, each composed of leading medical authorities and assisted by Sir John Cockcroft and Professor J. R. Squire, investigated on the one hand " the effects of radiation on the health of the individual exposed to it " (through his work or proximity to nuclear plants) and on the other " the possible genetic consequences of radiation to the population as a whole as well as to the individual and his descendants."

The dangers of radiation have been the subject of vigorous protests from many quarters throughout the world. Sir Ernest Rock Carling, consultant on radioactivity to the Atomic Energy Authority, warned a meeting of the British Medical Association last summer of the danger to fertility and mental health of the rising trend of radioactivity from bombs and nuclear power plants. He said that the natural background radiation has been raised by 25 per cent. already and that the danger level was reached when the natural background radiation had doubled. The genetists, said Sir Ernest, " foresee deterioration of the average intelligence, increase in mental disorder and considerable increase in the financial burden that will fall upon the healthy in maintaining the unhealthy in hospitals. . . . The radiation sins of the father are visited in the children for many years to come." Sir Ernest Rock Carling is not alone in being apprehensive. A recent meeting of the Sanitary Inspectors' Association expressed fears at letting radioactive materials " loose in industry." There is certainly an alarming lack of precise knowledge concerning the effects on background radiation of concentrated atomic energy production. The apprehension of the 300 employees of Thomas W. Ward employed at the Dounreay atomic power station who went on strike last month—pending the payment of " condition " money and the introduction of safety precautions on the site—cannot lightly be brushed aside. In the United States determined opposition developed to the operation of a fast-breeder reactor in Detroit. The Governor of Michigan and other eminent public men demanded the publication of a letter by the American Advisory Committee on Reactor Safeguards which sets forth its belief that " there is insufficient information available at this time to give assurance that the PRDC (Power Reactor Development Company, the Detroit reactor construction syndicate) can be operated at this site without public hazard " unless a small-scale prototype plant is built first. Despite this protest the building of the 100 MW fast-breeder reactor is going ahead. but the public outcry is gaining momentum.

Yet there is a growing feeling that the danger to the public from radiation is becoming less as the safety precautions improve. Mr. A. S. McLean, Group Medical Officer (Industrial Group), A.E.A., considers that the progress in the development of atomic energy in Britain has been reached in complete safety, " due largely to the fact that the atomic energy industry was probably the first major industry to adopt a thoroughly energetic attitude to the problem of health and safety as one of its first and most important terms of reference." He emphasises that this has had a pronounced impact on the design, construction and operation of atomic energy establishments and that the lack of " detailed information or advice about the criterion of radiological safety " placed a very heavy burden on the industry's engineers who had the highly complex task of making plant that was safe as well as efficient.

The next article in this series will describe the nature of the elaborate precautions that have been taken to reduce the hazards involved in operating atomic plants, in disposing of contaminated wastes and, on the positive side, the contribution atomic by-products have made to the advancement of medical science. Other considerations involved in the operation of atomic energy establishments—depreciation of plant, insurance, and the legal position—will also be discussed.

Pressure Vessels

In referring last week to the effect increased pressure-vessel thickness might have in raising reactor output we failed to mention a factor which is perhaps more important—and more obvious—than any other. The thicker the shell the larger the vessel which can contain a given pressure. Thus the maximum plate thickness that can be welded on site determines the reactor size; reactor size in turn is a measure of output.

On page 413 of our issue of September 28 we referred to the appointment of Mr. G. P. Davidson as head of the nuclear power plant activities of Head, Wrightson and Company, Limited. Unfortunately, the address given was that of Head, Wrightson Processes Limited; it should have been Teesdale Ironworks, Thornaby-on-Tees, Yorkshire.

SHOT BLASTING WITH STEEL ABRASIVE

Adaptability and Economy

Steel shot, which has not hitherto been available in this country, is now being produced for use in shot-blasting machines by Bradley's (Darlaston), Limited, Darlaston, South Staffordshire. The shot, which is made from a carbon steel of tool-steel quality, is heat treated, and has a tempered martensite micro-structure, which gives it a remarkable degree of toughness, solidity, and uniformity.

The steel shot is manufactured by a process somewhat similar to that which is used for chilled cast iron shot, that is, the metal is melted and blown into water, which quenches it in globular form. The steel is melted in electric furnaces, and the specification is kept under strict laboratory control. Quenching likewise, is carried out under very closely-controlled conditions in order to produce shot which is uniform both metallurgically and physically. After quenching and drying, the shot is heat treated in specially designed furnaces; after this heat treatment it has a Vickers Pyramid hardness of approximately 460, and is hard, tough and resilient. It only remains to grade the shot according to size.

Chilled iron shot is usually graded in British Standard sieve sizes, but steel shot grading is based on Society of American Engineers' standards, and the grade number gives an indication of the actual size of the shot. A screen with 0·078 in. aperture would, for example, pass the majority of the largest of the shot grades, S.780, while screen apertures of 0·007 in. would pass most of the S.70 grade.

Steel shot does not shatter on impact as cast iron does, and independent tests have shown that as a consequence the rate of shot consumption is much lower. The average shot consumptions over three tests, for example, were 6·7 lb. per wheel hour with steel shot, and 43·1 lb. per wheel hour with chilled iron shot. This increased life alone would be sufficient to justify the use of steel shot, although it is more expensive in first cost than iron, but the improved performance is not the only advantage possessed by steel. Wheel wear, for example, is reduced when steel shot is used, as is the effect on other wearing parts of the shot-blasting equipment. The high resilience of steel shot is also an advantage in that the kinetic energy of the abrasive is not completely expended in the first impact, and shielded areas are therefore cleaned at an increased rate. The surface finish produced by steel shot has a more matt appearance than that resulting from the use of iron abrasive, an effect which is mainly due to the frictional action, as distinct from shatter, of the steel shot at the point of contact. A process where the characteristics of steel shot render it noticeably superior, althoughiron shot can be and is used, is shot peening.

An application in which steel shot has obvious advantages is shot blasting of sheet steel for porcelain enamelling, and the de-enamelling of sheet steel components which have a faulty or damaged enamel surface, ready for re-enamelling. In such work as this there is always a risk that the enamel will be contaminated by the presence of iron particles produced when chilled iron shot shatters; the use of steel shot involves no such risk.

Another application of steel shot which takes advantage of the anti-shatter properties of steel is in the de-scaling of stainless steel wide strip. With such a highly-finished material no risks can be taken, and the fact that iron shot would shatter and leave particles which could discolour the surface, precluded the use of shot blasting until steel shot became available. De-scaling is now carried out in a wide strip mill by means of a continuous shot blast plant using steel shot, through which the strip passes.

FORTHCOMING EXHIBITIONS AND CONFERENCES

This list, arranged chronologically, appears in the last issue of each month. Events appearing for the first time, and alterations of dates, places, etc., are indicated by an asterisk (*). Particulars of exhibitions and conferences not included below may have appeared in ENGINEERING, *August* 31, *page* 287; *or September* 28 *page* 415. *Organisers are invited to send to the Editor particulars of coming events as soon as arrangements are made.*

Business Equipment Show.—Tues., Oct. 30, to Thurs., Nov. 1, at Mount Royal Hotel, Montreal. Apply to Mr. R. T. Grimes, Management Association, c/o Kraft Foods, Ltd., P.O. Box 6118, Montreal 2, Canada.

BEAMA Conference on Public Relations and Publicity.—Wed., Oct. 31, in London. Organised by the British Electrical and Allied Manufacturers' Association, 36–38 Kingsway, London, W.C.2. Tel. HOLborn 0502.

British Institute of Management, Congress.—Wed., Oct. 31, to Fri., Nov. 2, at Harrogate. Theme: "Management, Profits and Living Standards." Organised by the British Institute of Management, 8 Hill-street, London, W.1. Tel. GROsvenor 6000.

Gold Coast Government Housing Exhibition.—In November at Accra. Apply to the United Kingdom Trade Commissioner, Angelina House, Boundary-road, Accra, Gold Coast.

***Newer Interpretations of Reactions and Structure in Carbohydrate Chemistry, Symposium.**—Thurs., Nov. 1, in the Chemistry Department, University College London, Gower-street, W.C.1. Organised by the Chemical Society, Burlington House, Piccadilly, London, W.1. Tel. REGent 0675.

***Oil Firing of Industrial and Commercial Boiler Plants, Conference.**—Thurs., Nov. 1, at the Berkeley Hall of St. Andrew's Hall, Glasgow. Organised by the Combustion Engineering Association, 6 Duke-street, St. James's, London, S.W.1. Tel. WHItehall 5536.

Packaging Exhibition, Ninth International.—Thurs., Nov. 1, to Fri., Nov. 9, in Paris. Exhibition offices: 40 Rue du Colisée, Paris 8e.

Mechanical Handling Exhibition.—Thurs., Nov. 1, to Fri., Nov. 9, at Paris. Organised by the Salon de la Manutention, 40 Rue du Colisée, Paris 8e.

Bottling Exhibition, Tenth International.—Sat., Nov. 3, to Mon., Nov. 12, in Paris. Organised by the Salon International du Materiel d'Embouteillage et des Industries Connexes, 28 Rue Louis-le-Grand, Paris 2e.

Dairy Equipment Exhibition.—Sat., Nov. 3, to Mon., Nov. 12, in Paris. Apply to the Commissaire-General, Salon International de l'Equipement Laitier, 28 Rue Louis-le-Grand, Paris, 2e.

Arizona State Fair.—Sat., Nov. 3, to Mon., Nov. 12, at Phoenix, Arizona, U.S.A. United Kingdom exhibit. Information from British Consulate General, 448 South Hill-street, Los Angeles 13, Cal., U.S.A.

Canadian National Packaging Exhibition.—Tues., Nov. 6, to Thurs., Nov. 8, at Toronto. Organised by the Packaging Association of Canada, 1 St. Clair-avenue West, Toronto 7.

Hotel and Catering Equipment Exhibition.—Thurs., Nov. 8, to Mon., Nov. 19, in Paris. *Agent:* Mr. R. C. Liebman, 178 Fleet-street, London, E.C.4. Tel. CITy 5889.

Agricultural Aviation Show.—Fri. and Sat., Nov. 9 and 10, at Palmerston North, New Zealand. Organised by the Agricultural Aviation Show, P.O. Box 614, Palmerston North, New Zealand.

Royal Agricultural Winter Fair.—Fri., Nov. 9, to Sat., Nov. 17, at Toronto. Apply to Royal Winter Fair, Exhibition Park, Toronto 2B, Canada.

Cycle and Motor-Cycle Show, 31st International.—Sat., Nov. 10, to Sat., Nov. 17, at Earl's Court, London, S.W.5. Organised by the British Cycle and Motor-Cycle Industries Association, Ltd., The Towers, Warwick-road, Coventry (Tel. Coventry 62511); and 20-23 Lincoln's Inn Fields, London, W.C.2. Tel. CHAncery 4152.

British Occupational Hygiene Society, Conference.—Mon., Nov. 12, at London School of Hygiene and Tropical Medicine, Keppel-street, London, W.C.1. Theme: "Fires in Industry." Apply to Dr. D. Turner, Medical Research Council Laboratories, Holly-hill, Hampstead, London, N.W.3.

Public Works and Municipal Services Congress and Exhibition.—Mon., Nov. 12, to Sat., Nov. 17, at Olympia, London, W.14. Organised by the Municipal Agency, Ltd., 70 Victoria-street, London, S.W.1. Tel. VICtoria 9132.

***Sheffield and District Foundry Exhibition.**—Wed., Nov. 14, to Sat., Nov. 17, at the Drill Hall, Edmund-road, Sheffield. Apply to Mr. W. H. Bolton, secretary, Sheffield Section, National Trades Technical Societies, 234 Brookhill, Sheffield, 3. Tel. Sheffield 28581.

***Degree and Diploma Courses in Applied Physics, Conference.**—Thurs. and Fri., Nov. 15 and 16, at the Institution of Electrical Engineers, Savoy-place, Victoria-embankment, W.C.2. Organised jointly by the London and Home Counties Regional Advisory Council for Higher Technological Education; and by the Institute of Physics, 47 Belgrave-square, London, S.W.1. Tel. SLOane 9806.

Chemical Sciences Convention.—Sun., Nov. 18, to Mon., Dec. 3, in Paris. Convention will include the

29th International Congress of Industrial Chemistry, Sun., Nov. 18, to Sat., Nov. 24, at 28 Rue Saint-Dominique, Paris 7e;

First European Congress on Corrosion, Sun., Nov. 18, to Sat., Nov. 24, at 28 Rue Saint-Dominique, Paris 7e;

European Conference on Chemical Engineering, Thurs., Nov. 22, to Sat., Nov. 24, at the Palais des Congrès, Porte de Versailles, Paris; and

Technical Meetings on such subjects as Plastics, Rubber and Special Steels, Mon., Nov. 26, to Fri., Nov. 30, and Mon., Dec. 3, at the Palais de Congrès, Porte de Versailles, Paris. Apply, in each case, to the Société de Chimie Industrielle, 28 Rue Saint-Dominique, Paris 7e. *Agents:* Butler's Advertising Service, 22 St. Giles High-street, London, W.C.2. Tel. TEMple Bar 5905.

***Calder Works Nuclear Power Plant, Symposium on.**—Thurs. and Fri., Nov. 22 and 23, at the Institution of Civil Engineers, Great George-street, and the Central Hall, London, S.W.1. Organised by the British Nuclear Energy Conference, 1-7 Great George-street, London, S.W.1. Tel. WHItehall 4577. (Additional meeting place.)

National Boat Show.—Fri., Nov. 23, to Sun., Dec. 2, at Seattle. Apply to Mr. William C. Speidel, Jr., 800 Eighth-avenue, Seattle 4, Washington, U.S.A.

Bogota International Fair, Third.—Fri., Nov. 23, to Sun., Dec. 9, at Bogota. Apply to Corporacion de Ferias y Exposiciones, Edificio Avenida, Carrera 5A, Nos. 15-11, Bogota, Colombia.

***Teaching Electrical Housecraft, Conference.**—Sat., Nov. 24, at Battersea Polytechnic, London, S.W.11. Organised by the Electrical Association for Women, 25 Foubert's-place, London, W.1. Tel. GERrard 5215.

Power and Mechanical Engineering, 22nd National Exposition.—Mon., Nov. 26, to Fri., Nov. 30, at the Coliseum, Columbus Circle, New York. Held under auspices of American Society of Mechanical Engineers, 29 West 39th-street, New York 18. *Managers:* International Exposition Co., 480 Lexington-avenue, New York 17.

Automation Exposition, Third International.—Mon., Nov. 26, to Fri., Nov. 30, at 500 Eighth-avenue, New York. During the exposition, two-day conferences will be held on "Automation for the Office," "Human Engineering for Automation," and "Conveyors for Automation." Organised by Richard Rimback Associates, 845 Ridge-avenue, Pittsburg 12, Pa., U.S.A. *Agents:* T. G. Scott and Sons, Ltd., 143/147 Regent-street, London, W.1. Tel. REGent 3891.

Chemical Exhibition, National.—Tues., Nov. 27, to Fri., Nov. 30, at Cleveland, Ohio. Organised by the American Chemical Society, 86 E. Randolph-street, Chicago 1, Ill., U.S.A.

Cycle and Motor-Cycle Exhibition, 34th.—Sat., Dec. 1, to Mon., Dec. 10, at Milan. Organised by the Italian Association of Manufacturers of Cycles, Motor-Cycles and Accessories, Via Mauro Macchi 32, Milan, Italy.

Smithfield Show and Agricultural Machinery Exhibition.—Mon., Dec. 3, to Fri., Dec. 7, at Earl's Court, London, S.W.5. Apply to the exhibition manager, Smithfield Show Joint Committee, 148 Piccadilly, London, W.1. Tel. GROsvenor 4040.

***Radiology Annual Congress and Exhibition.**—Thurs. and Fri., December 6 and 7, at the Caxton Hall, off Victoria-street, London, S.W.1. Organised by the British Institute of Radiology, 32 Welbeck-street, London, W.1.

National Boat Show. Third.—Tues., Jan. 1, to Sat., Jan. 12, 1957, in the Empire Hall, Olympia, London, W.14. Organised by the Ship and Boat Builders' National Federation, 205 Regent-street, London, W.1. Tel. REGent 1108.

Packaging Exhibition.—Tues., Jan. 22, to Fri., Feb. 1, 1957, at Olympia, London, W.14. Held in collaboration with the Institute of Packaging, and organised, in association with F. W. Bridges and Sons, Ltd., by Provincial Exhibitions, Ltd., City Hall, Deansgate, Manchester, 3. Tel. Deansgate 6363.

***Western Springs Trade Exhibition.**—Sat., Jan. 26, to Sat., Feb. 9, 1957, at Auckland, New Zealand. Apply to Auckland Provincial Public Relations Office, Achilles House, 45 Customs-street East, Auckland C.1, New Zealand.

***Hi Fi Electrical and Radio Show.**—Wed., Feb. 6, to Sat., Feb. 9, 1957, in Los Angeles, California. Organised by the Institute of Hi-Fi Manufacturers, 28 Broad-street, New York 4, U.S.A.

Scottish Dairy Show.—Tues., Feb. 12, to Fri., Feb. 15, 1957, at Kelvin Hall, Glasgow. Organised jointly by the Corporation of Glasgow and the Scottish Agricultural Society. Apply to Mr. Walter Barlow, Kelvin Hall, Glasgow. Tel. Kelvin 1185.

Mechanical Engineers' Contribution to Clean Air, Conference on.—Tues., Feb. 19, to Thurs., Feb. 21, 1957, in London. Organised by the Institution of Mechanical Engineers, 1 Birdcage-walk, St. James's Park, London, S.W.1. Tel. WHItehall 7476. See also page 519 in this issue.

***Boat Show, International.**—Fri., Feb. 22, to Wed., Feb. 27, 1957, in Miami. Offices: 615 S.W. 2nd-avenue, Miami, Florida, U.S.A.

Hardware Trades Fair, Third.—Mon., Feb. 25, to Fri., Mar. 1, 1957, at the Royal Horticultural Society's Old and New Halls, Vincent-square and Greycoat-street, London, S.W.1. Organised by Universal Exhibitions Ltd., 74 Holland Park, London, W.11. Tel. PARk 7723.

Food, Cookery and Catering Trades Exhibition.—Tues., Feb. 26, to Sat., Mar. 9, 1957, at the City Hall, Deansgate, Manchester. Organised by Provincial Exhibitions Ltd., City Hall, Deansgate, Manchester, 3. Tel. Deansgate 6363.

Metals under High Rates of Strain, Conference on.—In March, 1957, probably in London. Organised by the Institution of Mechanical Engineers, 1 Birdcage-walk, St. James's Park, London, S.W.1. Tel. WHItehall 7476.

***Copenhagen International Fair.**—*Technical Fair*: Tues., Mar. 5, to Wed., Mar. 13, 1957. *Commercial Fair*: Sat., Mar. 23, to Sun., Mar. 31, 1957. In Copenhagen, Denmark. Organised by the International Messe, Vester Farimagsgade 6, Copenhagen V, Denmark. *Agents* Auger and Turner Group, Ltd., 40 Gerard-street, London, W.1. Tel. GERrard 6671.

Ideal Home Exhibition.—Tues., Mar. 5, to Sat., Mar. 30, 1957, at Olympia, London, W.14. Organised by Associated Newspapers Ltd., 161-163 Queen Victoria-street, London, E.C.4. Tel. FLEet 6000.

***Atomic Exposition and Nuclear Congress, International.**—Mon., Mar. 11 to Fri., Mar. 15, 1957, at the Convention Hall, Philadelphia. Apply to Mr. H. F. Grebe, International Atomic Exposition, 117 South 17th-street, Philadelphia 3, Pa., U.S.A.

***Kansas City, International Trade Fair.**—Sun., Mar. 17, to Sun., Mar. 24, 1957, at Kansas City. Apply to Mr. L. L. Bratschie, Heart of America International Trade Fair, Inc., 3230 Broadway, Kansas City, 11, Missouri, U.S.A.

***Photographic Exposition, International.**—Fri., Mar. 22, to Sun., Mar. 31, 1957, at the National Guard Armory, Washington. Apply to Mr. R. J. Wilkinson, International Photographic Exposition, 104 East Michigan-avenue, Jackson, Michigan, U.S.A.

Physical Society's Exhibition of Scientific Instruments and Apparatus.—Mon., Mar. 25, to Thurs., Mar. 28, 1957, in the Royal Horticultural Society's Old and New Halls, Vincent-square and Greycoat-street, London, S.W.1. Organised by the Physical Society, 1 Lowther-gardens, Prince Consort-road, London, S.W.7. Tel. KENsington 0048.

***Western Metal Congress and Exhibition.**—Mon., Mar. 25, to Fri., Mar. 29, 1957, in the Pan Pacific Auditorium, Los Angeles, California. Organised by the American Society for Metals, 7301 Euclid-avenue, Cleveland 3, Ohio, U.S.A.

Radio Component Show, 14th.—Tues., April 9, to Thurs., April 11, 1957, at Grosvenor House, Park-lane, London, W.1. Pre-view for overseas and special guests on Mon., April 8. Annual private exhibition organised by the Radio and Electronic Component Manufacturers' Federation, 21 Tothill-street, London, S.W.1. Tel. ABBey 4226. Applications for admission must be made in advance.

Chemical Engineering Education Symposium.—Tues., April 9, to Thurs., April 11, 1957, at The University, Birmingham. Organised by the Midlands Branch, Institution of Chemical Engineers. Apply to the secretary of the Institution, 16 Belgrave-squre, London, S.W.1. Tel. BELgravia 3647.

Electrical Engineers' Exhibition, Sixth.—Tues., April 9, to Sat., April 13, 1957, at Earl's Court, London, S.W.5. Sponsored by the Association of Supervising Electrical Engineers, 23 Bloomsbury-square, London, W.C.1. Apply to Mr. P. A. Thorogood, Electrical Engineers (A.S.E.E.) Exhibition, Ltd., 6 Museum House, 25 Museum-street, London, W.C.1. Tel. MUSeum 3450.

United States World Trade Fair.—Sun., April 14, to Sat., April 27, 1957, at the New York Coliseum, New York. *Managers:* The Charles Snitow Organisation, Inc., 331 Madison-avenue, New York, 17. Information may be obtained from the British Commonwealth Chamber of Commerce in the United States, 677 Fifth-avenue, New York, 22; and from the Fair's British and Commonwealth Office, Dudley House, 36 and 38 Southampton-street, London, W.C.2. Tel. TEMple Bar 8947.

***Materials Handling Exposition, National.**—Mon., April 29, to Fri., May 3, 1957, in the Convention Hall, Philadelphia. Apply to Clapp and Poliak Inc., 341 Madison-avenue, New York 17, U.S.A.

Factory Equipment Exhibition, Fifth.—Mon., April 29, to Sat., May 4, 1957, at Earl's Court, London, S.W.5. Theme: "Greater Efficiency in Industry." Organised by Factory Equipment Exhibitions, Ltd., 4 Snow-hill, Holborn-viaduct, London, E.C.1. Tel. CENtral 0354.

***Caribbean Exhibition.**—Fri., May 3, to Sun., May 19, 1957, at Port of Spain, Trinidad. Apply to the Junior Chamber of Commerce of Trinidad, Port of Spain, Trinidad.

***Japan International Trade Fair.**—Sun., May 5, to Sun., May 19, 1957, at Harumi Pier Grounds, Harumicho, Chuo-ku, Japan. Apply to Fair Management Office, Tokyo International Trade Fair Commission, c/o Economic Bureau, Tokyo Metropolitan Government, Marunouchi 3-Chome, Chiyoda-ku, Tokyo, Japan.

Industrial Tool and Production Show of Canada.—Mon., May 6, to Fri., May 10, 1957, in the Industry Building, Exhibition Park, Toronto. Apply to Mr. E. M. Wilcox, 19 Melinda-street, Toronto, Canada. (Alteration of dates.)

***Engineered Castings Show, First; and the 61st A.F.S. Castings Congress.**—Mon., May 6, to Fri., May 10, 1957, at Cincinnati Music Hall, Cincinnati, Ohio, U.S.A. Sponsored by the American Foundrymen's Society, Golf and Wolf-roads, Des Plaines, Illinois, U.S.A.

British Industries Fair.—Mon., May 6, to Fri., May 17, 1957, in the B.I.F. Buildings, Castle Bromwich, Birmingham. Organised and controlled by the Birmingham Chamber of Commerce. Apply to the organisers: P.O. Box 6, 95 New-street, Birmingham 2. Tel. Midland 5021.

Instruments, Electronics and Automation Exhibition, First.—Tues., May 7, to Fri., May 17, 1957, at Olympia, London, W.14. Promoted by the British Electrical and Allied Manufacturers' Association and four other trade associations. Organised by Industrial Exhibitions, Ltd., 105-106 New Bond-street, London, W.1. Tel. HYDe Park 9583.

***Protective Clothing and Safety Equipment Exhibition, First.**—Mon., May 13, to Fri., May 17, 1957, at Olympia, London, W.14. Organised by the U.T.P. Exhibitions Ltd. (Associate company of United Trade Press Ltd.), 43 Gerrard-street, London, W.1. Tel. GERrard 0727.

***Book Exhibition, Second International.**—Sun., May 26, to Thurs., May 30, 1957, at Sherman Hotel, Chicago. *Agent:* Mr. A. P. Wales, Dudley House, 36–38 Southampton-street, London, W.C.2. Tel. TEMple Bar 8947.

***Waikato Agricultural Winter Show.**—Sun., May 28, to Tues., June 4, 1957, in Hamilton, New Zealand. Apply to Mr. W. H. Paul, Box 616, Hamilton, New Zealand.

Bath and West Agricultural Show.—Wed., May 29, to Sat., June 1, 1957, at Swindon. Organised by the Bath and West and Southern Counties Society, 3 Pierrepont-street, Bath. Tel. Bath 3010.

***Electronics in Automation, Convention.**—In June, 1957, at King's College, Cambridge. Organised by the British Institution of Radio Engineers, 9 Bedford-square, Loncon, W.C.1. Tel. MUSeum 1901.

Internal-Combustion Engine Congress, Fourth International.—Mid-June, 1957, at Zürich. Apply to Mr. C. C. M. Logan, secretary, British National Committee, 6 Grafton-street, London, W.1. Tel. HYDe Park 5107. See ENGINEERING, December 2, 1955, page 753.

Three Counties Agricultural Show.—Tues., June 11, to Thurs., June 13, 1957, at Hartpury, Gloucester. Organised by the Three Counties Agricultural Society, Berrington House, 2 St. Nicholas-street, Hereford. Tel. Hereford 3969.

***British Commonwealth Welding Conference.**—Mon., June 17, to Sat., June 29, 1957, in London and Saltburn-by-Sea. Organised by the Institute of Welding, 2 Buckingham Palace-gardens, Buckingham Palace-road, London, S.W.1. Tel. SLOane 9851.

***Commercial and Scientific Exhibition.**—Mon., June 24, to Wed., June 26, 1957, at the Show Mart, Montreal. Held in conjunction with the 23rd Congress of the Catholic Hospitals of the Province of Quebec. Apply to the Comite des Hopitaux du Quebec, 325 Chemin Sainte-Catherine, Outremont, Montreal 8, Canada.

Exchange of Management Information, 11th International Conference.—Mon., June 24, to Fri., June 28, 1957, in Paris. Apply to the British Institute of Management, 8 Hill-street, London, W.1. Tel. GROsvenor 6000.

***Royal Agricultural Show.**—Tues., July 2, to Fri., July 5, 1957, at Costessey, Norwich. Organised by the Royal Agricultural Society of England, 35 Belgrave-square, London, S.W.1. Tel. BELgravia 5323.

***Electronics Exhibition and Convention, 12th Annual.**—Thurs., July 11, to Sat., July 13, and Mon., July 15, to Wed., July 17, 1957, at the College of Science and Technology, Manchester. Organised by the Northern Division of the Institution of Electronics, 20 Buckingham-street, London, W.C.2. Apply to Mr. W. Birtwistle, 78 Shaw-road, Thornham, Rochdale, Lancs. Tel. Oldham Main 6661.

***Engineering, Marine and Welding Exhibition (21st) and the Foundry Trades Exhibition.**—Thurs., Aug. 29, to Thurs., Sept. 12, 1957, at Olympia, London, W.14. Organised by F. W. Bridges and Sons, Ltd., Grand Buildings, Trafalgar-square, London, W.C.2. Tel. WHItehall 0568.

THE HUMAN ELEMENT

Dignity and status among the manually employed—Effects of the slump in the motor-car industry on employment in the Midlands—Problem of providing equal pay for railway men and women—American views on automatic methods in industry—de Havilland's rate fixers raise a tricky problem.

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Work and Snobbery

Much has been said and written about the dignity of work, but far less has been said about its snobbery. Yet this last is a vital factor in the general attitude towards employment. The wife of the plumber is as sure that she lives in a world apart from that of the wife of the plumber's mate, as is the consort of the managing director. The barriers are less apparent to the casual observer and the left-wing intellectual with a middle-class background, but they are there all the same and woe betide anyone who ignores them.

The process by which a job in the industrial hierarchy is upgraded is a subtle one. A particular kind of labour must become scarce and thus the job becomes difficult to fill. Its wages increase and those who earn them also earn increased civility. The job begins to assume a special identity and it is conceded that training may be required. Often as not the job changes its name and the gradual introduction, while this process is going on, of better tools and equipment reduces the manual content in it. The job is now fast climbing the ladder of industrial respectability. It may attract special clothes or a species of uniform. Unions vie with each other to organise it and it is on the verge of becoming a craft—almost a petty profession. The men concerned, and their wives, achieve a new and exciting respectability among their fellows. Their ability to trample socially on the grades lower down is correspondingly increased.

The latest phenomenon of this kind is the progression of dustmen to the title of refuse collectors. The final stage will be reached when everyone talks nostalgically about that romantic figure "the old dustman." Dramatic critics will write learnedly to prove that Shaw's Doolittle in *Pygmalion* was a gentleman after all. So be it, but let us remember that it is all because of scarcity, not training or ability.

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Employment in the Midlands

There are signs that the employment position in the Midlands is improving and the Midland Regional Board for Industry reports a small but definite fall in unemployment and short-time working. The change is particularly noticeable in respect to skilled and semi-skilled men, but, significantly, the position regarding unskilled labour is also getting better. There has been a slight worsening of the unemployment figures in some ways, but this has been due to a number of "technical reasons," such as women coming back on the register after the school holidays. In contrast, between August and September, there was a useful decline in the amount of recorded short-time working.

The ability of labour to find alternative employment is all to the good. After all, the object of the credit squeeze is to force workers into other jobs, not to put them on the streets. But the capacity of the Midlands labour market to absorb more workers suggests, if this trend should indeed continue, that the speed and extent of the reaction of other industries to changing prospects in the motor-car industry is rather less than had been thought. It had been expected that the tremendous influence which the motor industry exerts, as an assembly activity, on a wide range of ancillary industries would have been much greater. Alternatively, it may be that the reaction will be slower than has been thought likely and that its full impact may yet have to be felt, especially as the trend of car production continues to be far from reassuring to the manufacturers concerned. On the whole, it seems probable that the effect of the credit squeeze in industry in the Midlands, which is very much the guinea pig at the moment, is going to be more drawn out and complicated than either the forecasters or the latest official figures suggest.

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Equal Pay for Railway Clerks

During the hearing of a claim for "equal pay for equal work," which came before the Railway Staff National Tribunal last week, Mr. W. J. Webber, general secretary of the Transport Salaried Staffs' Association, attacked the Commission's proposals for limiting the application of the principle to cases when "equal work" could be clearly established. Should the Commission's proposals be accepted, only about half the 9,000 women and girls engaged on office work would be covered. Mr. Webber pointed out that, throughout the earlier discussions on equal pay, the Commission had quoted the Civil Service as a reason for not applying it to railway staffs, and stated: "Now that the Civil Service have applied it, I cannot see that it is wrong to suggest that it should be applied on the same conditions *in toto*, and not limited, in respect of the railway staff."

The disagreement between the Commission and the union centres on the interpretation of what constitutes equal work; that is, whether it should be confined to posts where there is equal responsibility with male employees in every respect, involving common recruitment, common qualifications, common conditions of employment and common performance of duties. Mr. Webber contended that the intermingling of clerical work in the starting grades of the railway service would make the imposition of any demarcation line difficult, if not impossible, and contended that such a course would be likely to cause "trouble and frustration," and prove a major handicap to the Commission's recruiting drive.

The Tribunal's task is far from easy. To concede Mr. Webber his case means, in practice, raising the wage levels of all female clerks to that of men, which would add £420,000 to the railway's £320 million wage bill. On the basis of arguments so far expounded, however, it seems unlikely that any other solution is practicable. Provided that jobs are properly graded and evaluated, irrespective of who shall perform them, there should be little room for disagreement. The trouble is that, in the railways, as in most other industries, job evaluation has hardly begun, and that tradition, coupled with market influences, shut out the application of anything resembling a wages policy.

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Labour Looks at Automation

Automation will end time studies and incentive rates, require completely new job classifications and wage structures, and will make the protection of the older worker one of the main functions of trade unions. It will make possible safer and healthier working conditions and will bring about a greater humanisation of industry. There will be, too, new problems and new incentives, in the setting up of medical and education services.

The above are the bare headings of two special articles, written only two months ago, one by an American trade union leader, and the other by the head of the U.S. Industrial Hygiene Foundation. How radical a change in established practices these men envisage being brought about (and they have at least some evidence on which to base their remarks) is best shown by quoting the opening remarks of Mr. Jack Conway of the United Automobile Workers' Union: "When applied to the startling advances in basic human knowledge, automation transforms industrial and commercial life. Traditional concepts and familiar scenes are disappearing. Production is being redesigned. Factory size and location will be changed. Compartmentalised engineering as it exists to-day is obsolete."

Mr. Conway writes as if the production methods which made his industry the biggest in the world had already been swept away. He is much concerned with the need for new skills in automatic factories and with the union's function to ensure that retraining facilities will be provided for displaced workers, so that there is no wastage of labour potential. Management, he considers, must bear an appropriate share of the social cost of the change, and the unions must see to it that the cost of retraining an older worker is the same as hiring an already trained young worker—either by paying for the latter's training or by receiving State help to retrain the former.

Mr. Conway makes it clear that his union anticipates that wage rates, job classifications, seniority grouping, and wage payment methods will become obsolete. Unions must, he contends, "maintain maximum freedom to exert their full influence in the shaping of that structure." Dr. C. R. Walmer, of the Hygiene Foundation, foresees a radical change in the living and working habits, in work environment, educational patterns and a sharp rise in living standards. He concludes that the increased dependence of the new techniques in good mental and physical health of workers will make a comprehensive system of preventive health maintenance "essential and an economic proposition." In this, at least, Britain will be well placed.

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Rating the Rate Fixers

A novel issue was raised last week at de Havilland's Broughton factory when 40 rate fixers downed stop watches in support of their claim that their wages should be on the same basis as those of productive workers. The management refused to entertain the idea, though they have since agreed to hold a meeting to review "salary gradings." They doubtless feared that, given such an incentive, the rate fixers might quickly raise earnings even beyond those of the managers themselves. Now the word "salary" has crept in, with the social distinction it implies. Rate fixers are there to see that financial incentives to higher output result in lower production costs. If it were their own wages that were at stake, there would doubtless be much improved relationships between them and their colleagues, but this growth in solidarity, however desirable in itself, could hardly promote an objective outlook.

De Havilland's management may solve the problem by altering the status of rate fixers. Yet there is a tendency in manufacturing industry to allow production workers themselves to fix one another's rates, with highly satisfactory results claimed by managements. This departure from age-old practice is based on the belief that objectivity is a much under-rated quality in the British worker. Give two lathe operators the chance to time one another (with elementary training in the use of a stop watch) and resulting times are likely to prove much more realistic and accurate than could be obtained by the rate-fixing department or, for that matter, by an outside consultant.

Protagonists of this method say that it is the only way to obtain reliable results. They also claim it is the quickest way to get the rates accepted as fair by the operators themselves. As most managements know only too well, to fix a rate is one thing, while to "sell it" to the workers concerned is quite another. Yet, without the latter's concurrence, the result can be increased friction rather than increased output.

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